

The importance of Aura MLS to understanding stratospheric water vapor

A. E. Dessler

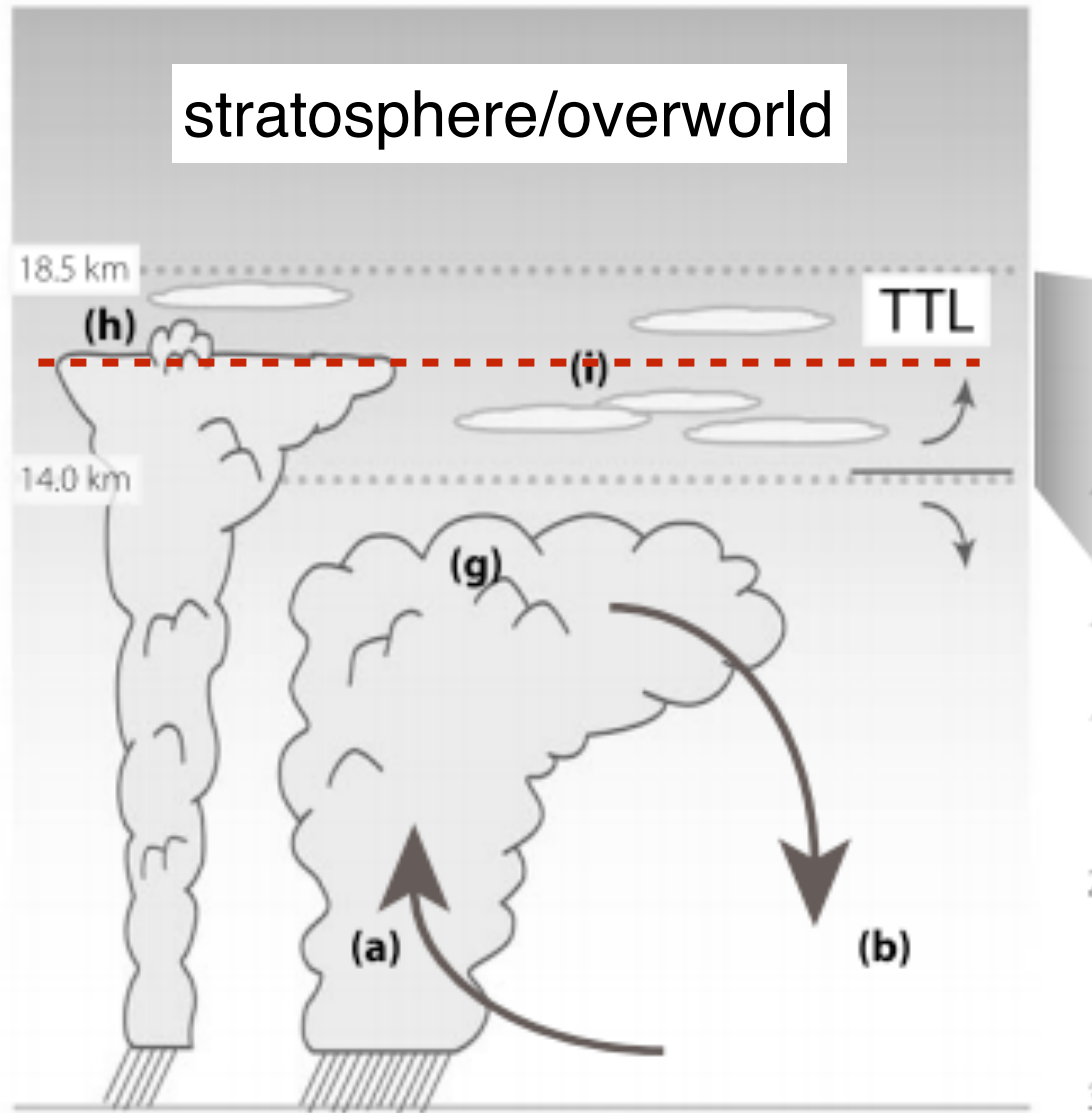
Dept. of Atmospheric Sciences

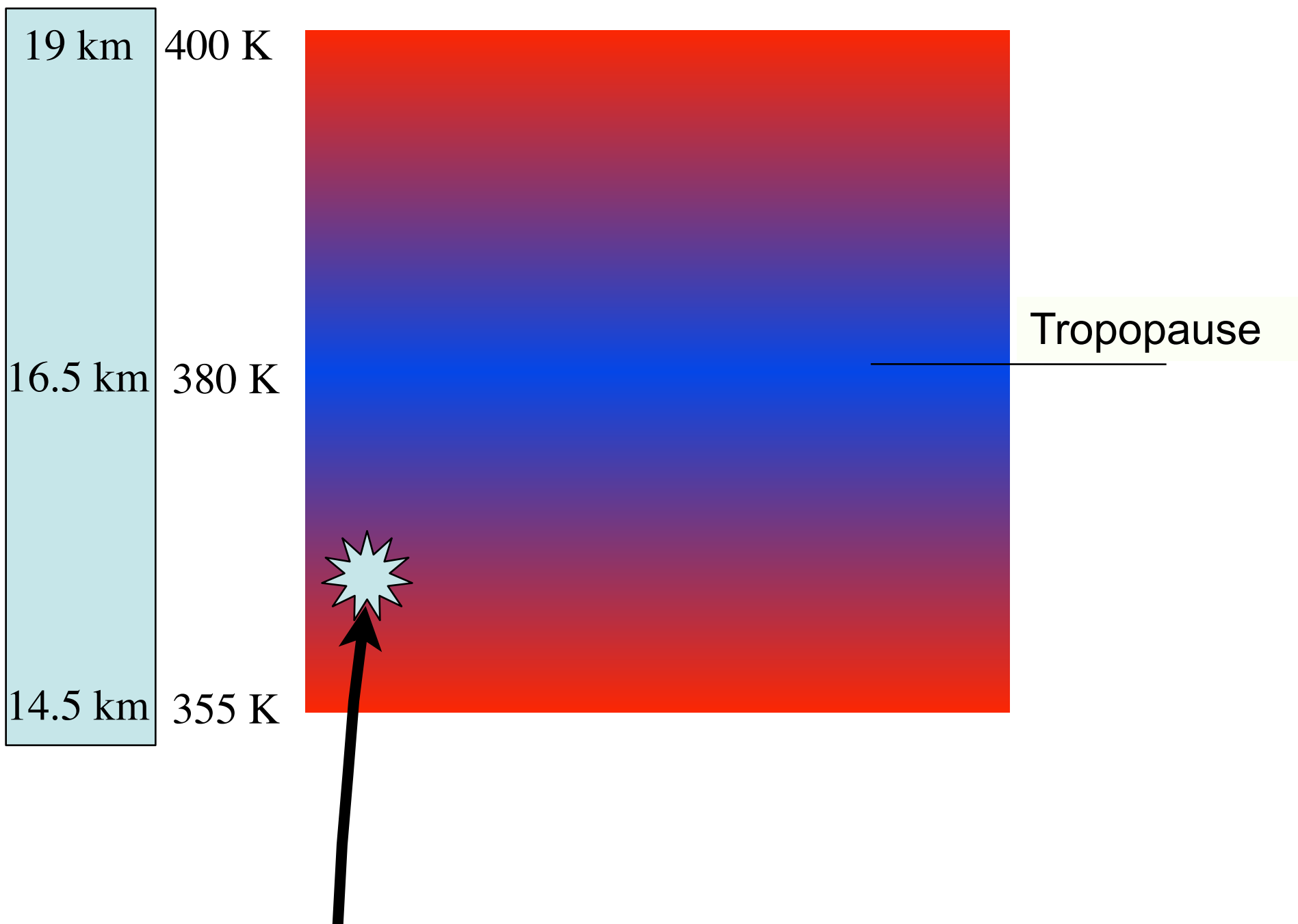
Texas A&M University

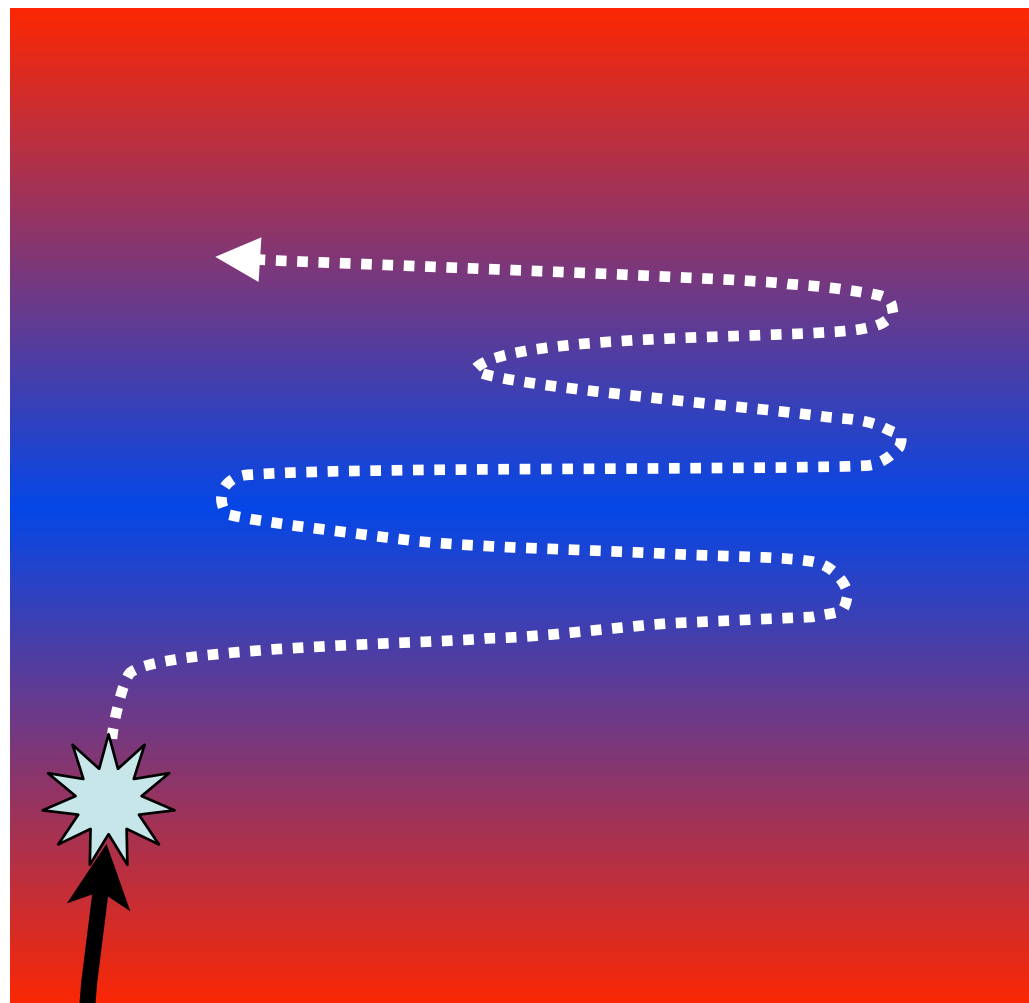
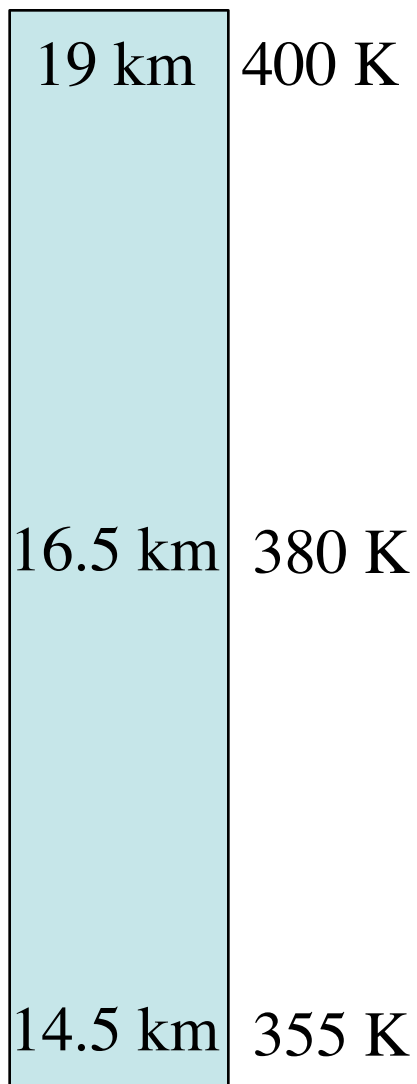


stratosphere/overworld

tropopause



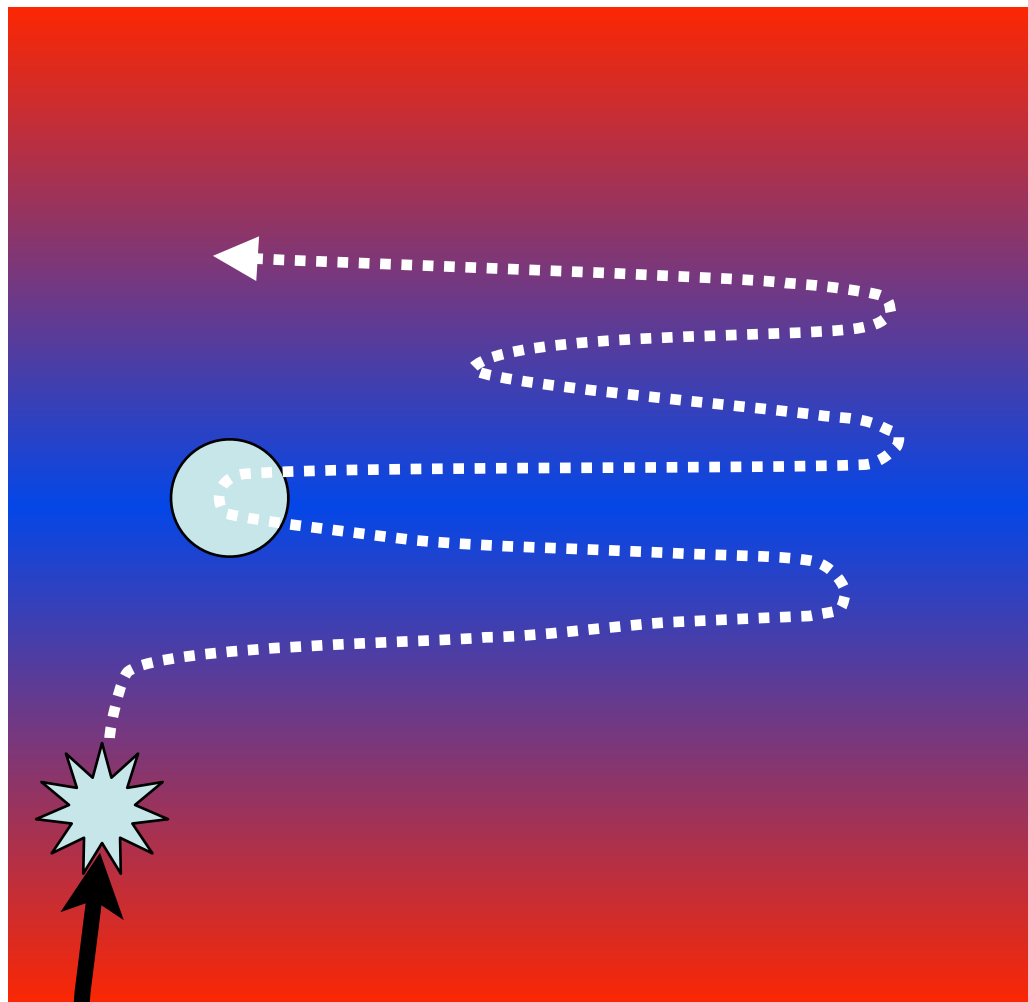




400 K

380 K

355 K

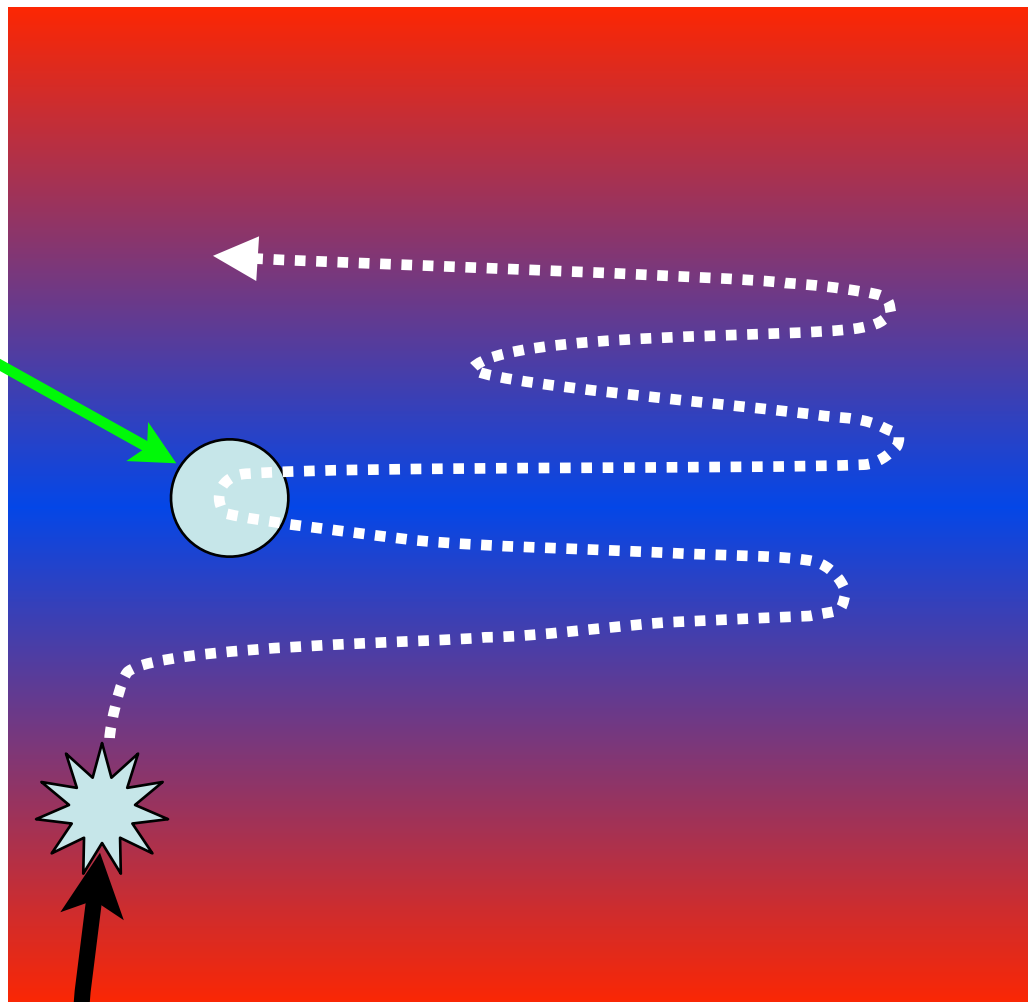


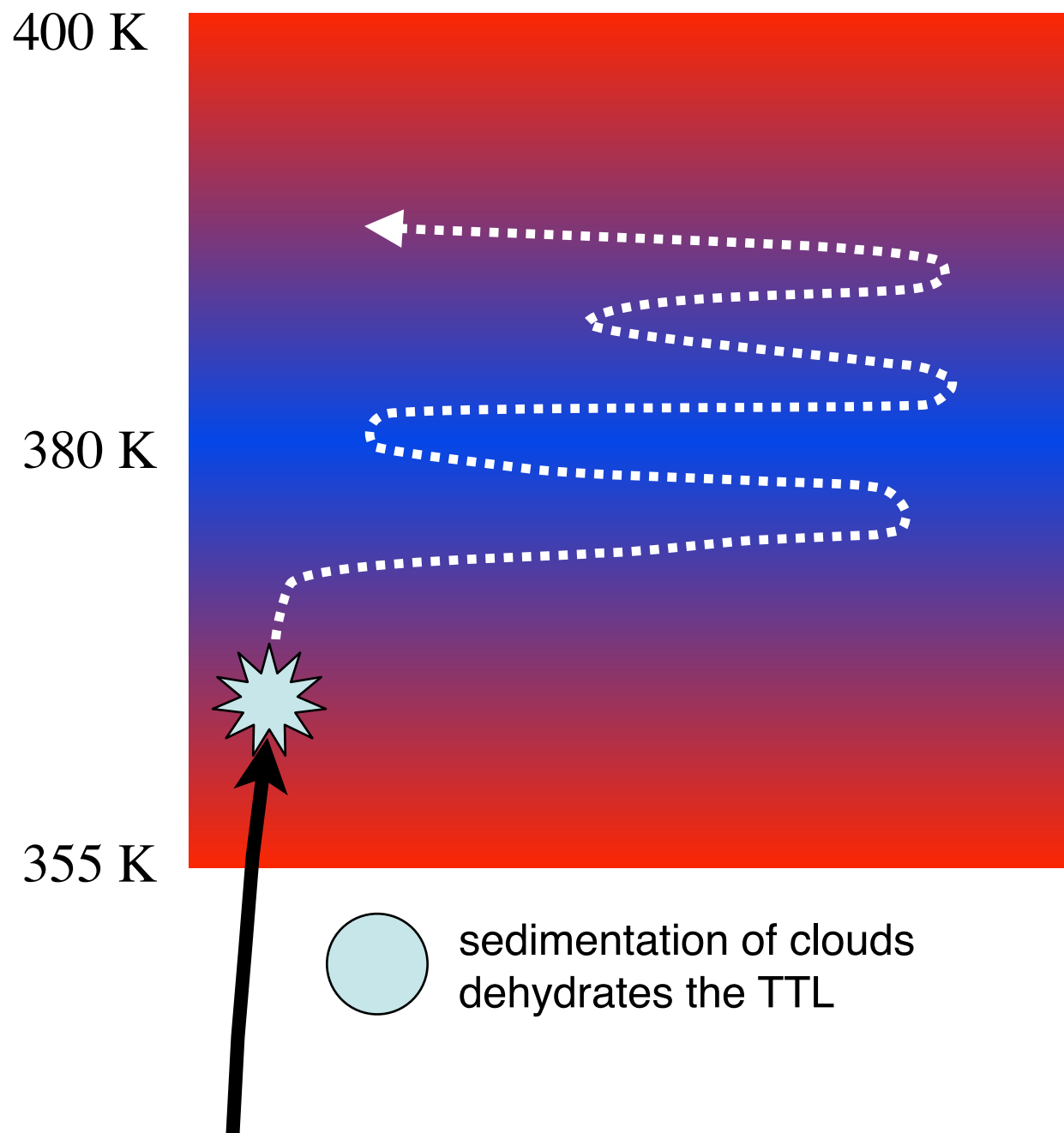
400 K

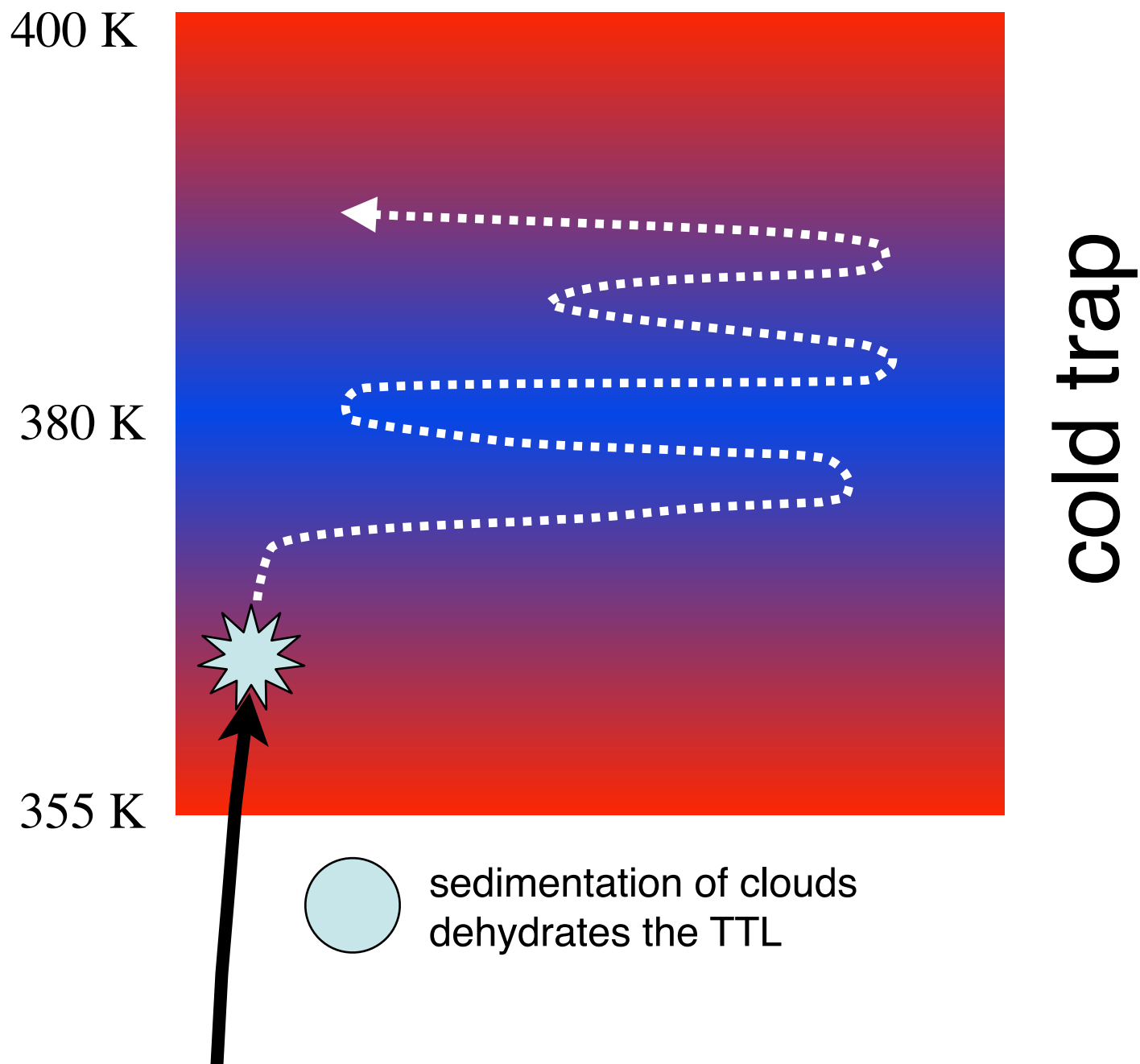
cold temperature
generate clouds

380 K

355 K



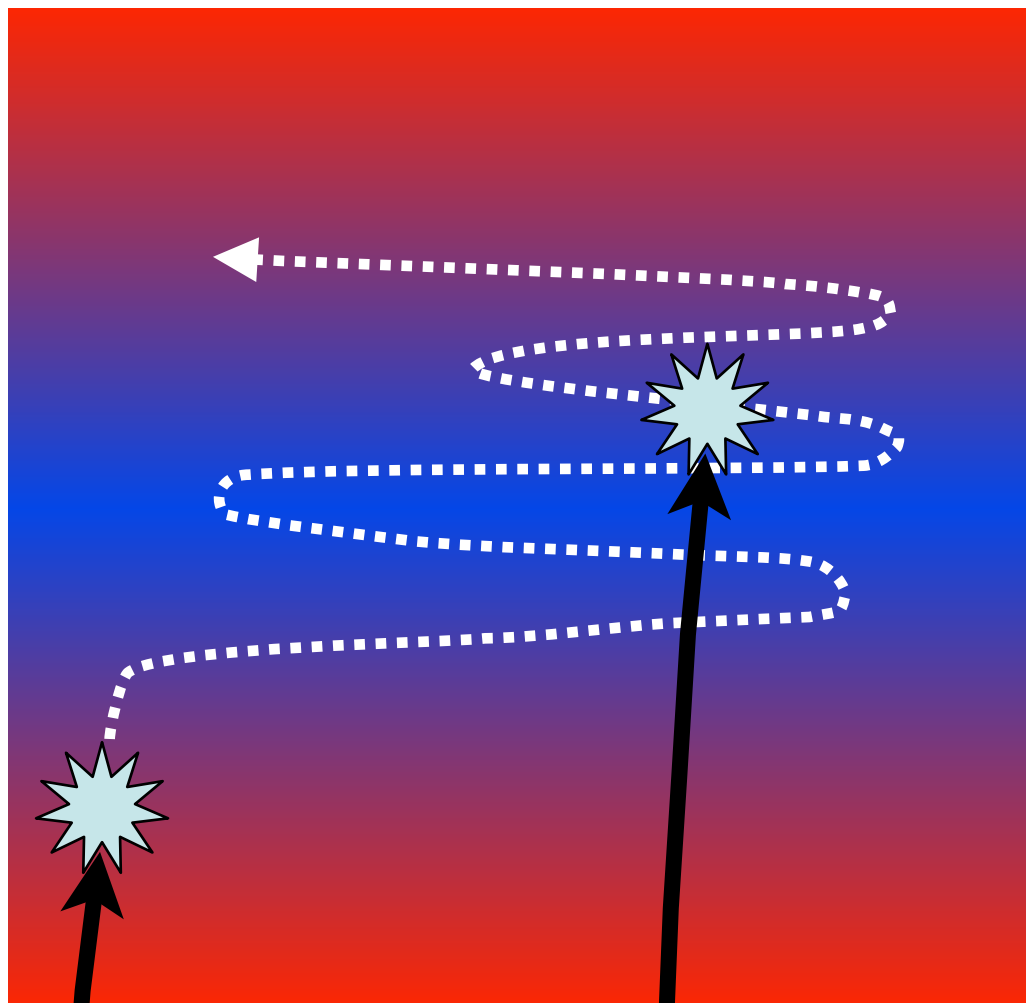




400 K

380 K

355 K



Aura advances in stratospheric water vapor

- Large-scale temperatures & transport
- Microphysics & unresolved temperature fluctuations
- Convection

Aura advances in stratospheric water vapor

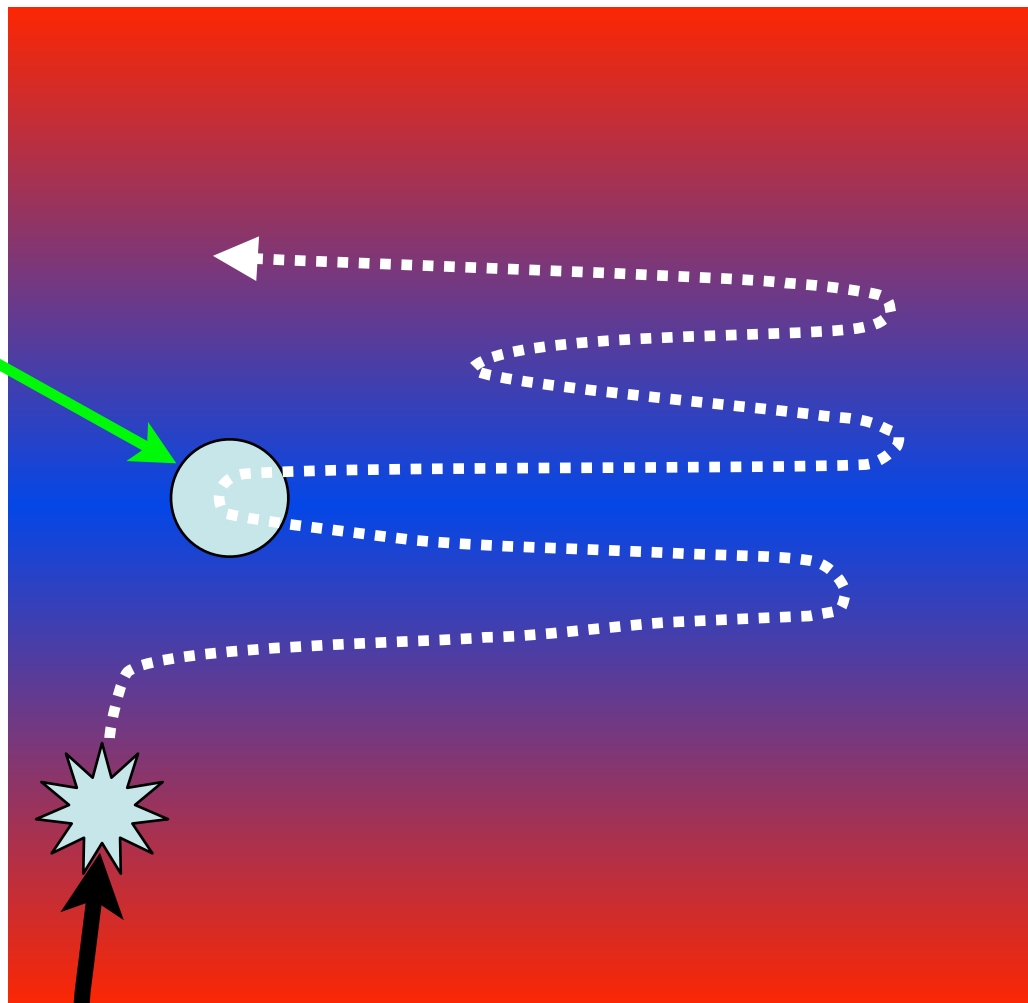
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400 K

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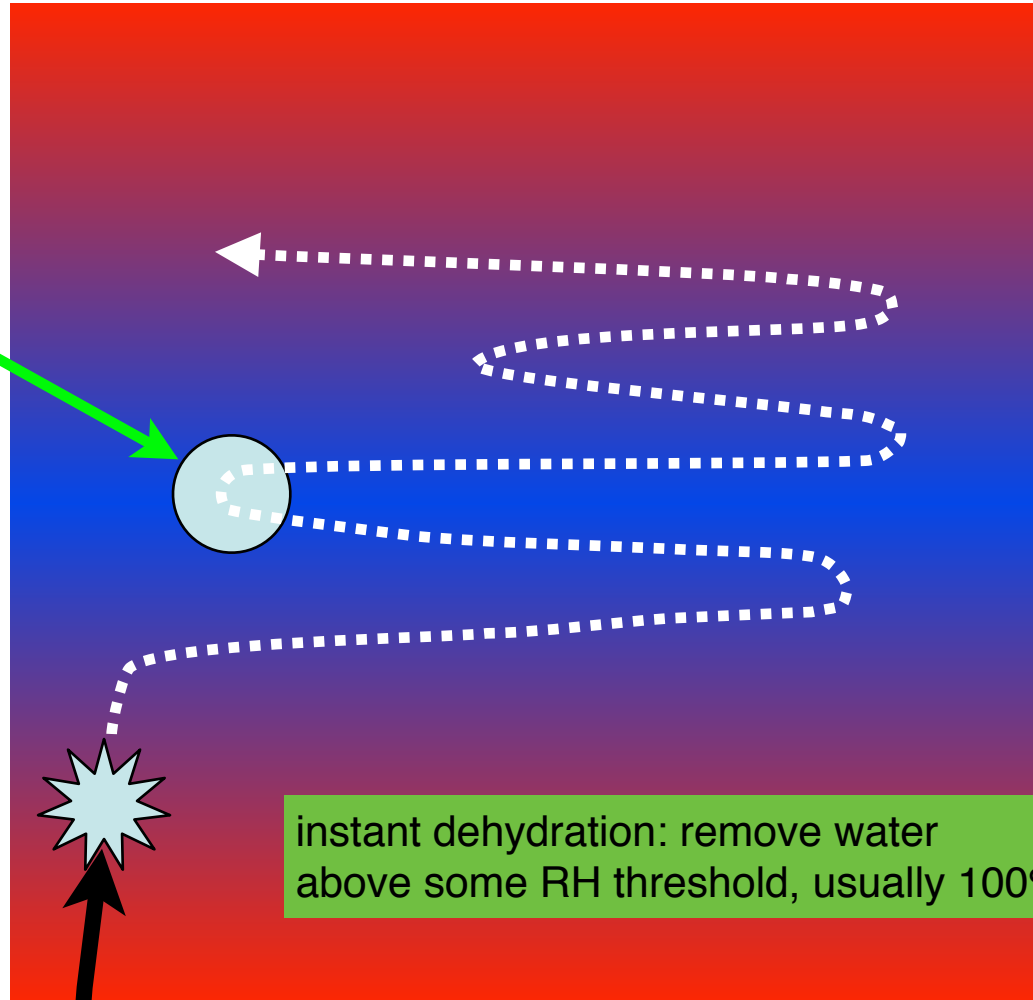
Before Aura, there was a good understanding that large-scale temperatures were the primary controller for water vapor

400 K

cold temperature
generate clouds

380 K

355 K



instant dehydration: remove water
above some RH threshold, usually 100%

Before Aura, there was a good
understanding that large-scale
temperatures were the primary
controller for water vapor

400 K

water in stratosphere is determined
solely by cold point temperature

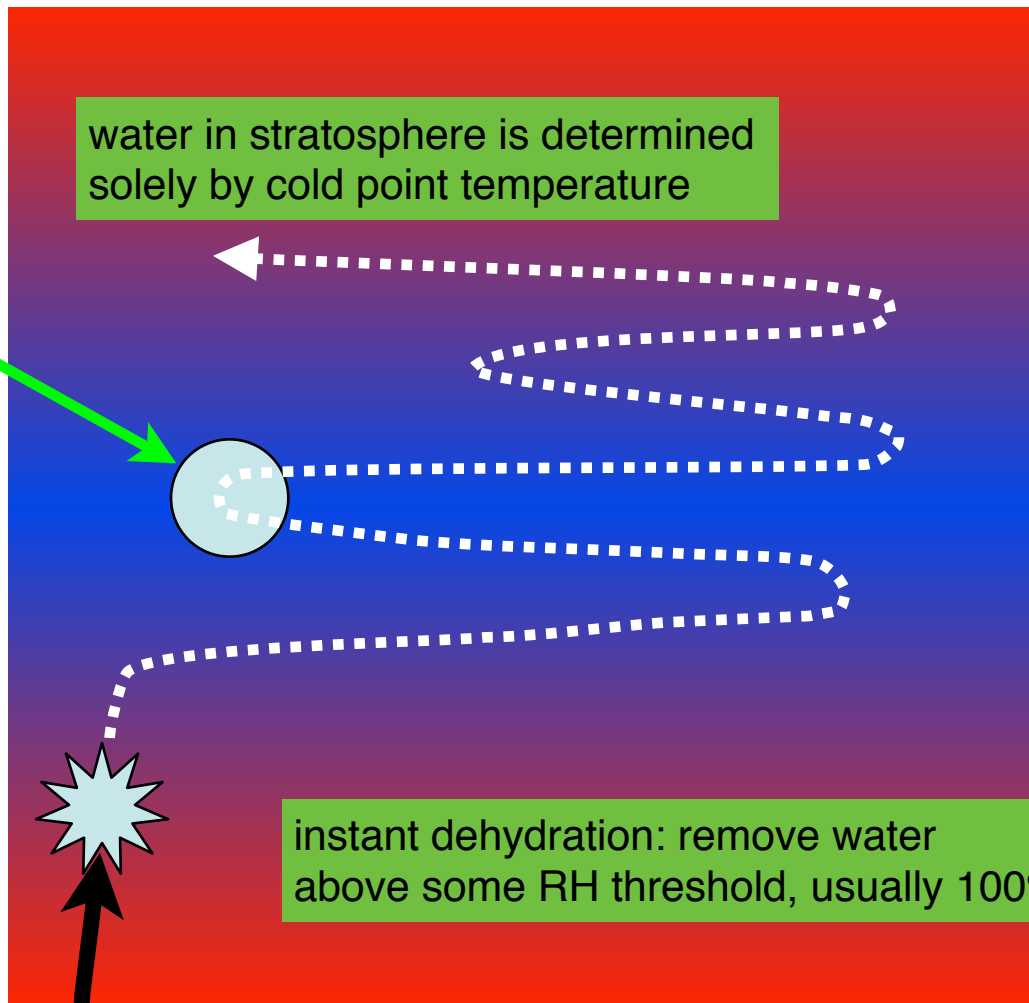
cold temperature
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400 K

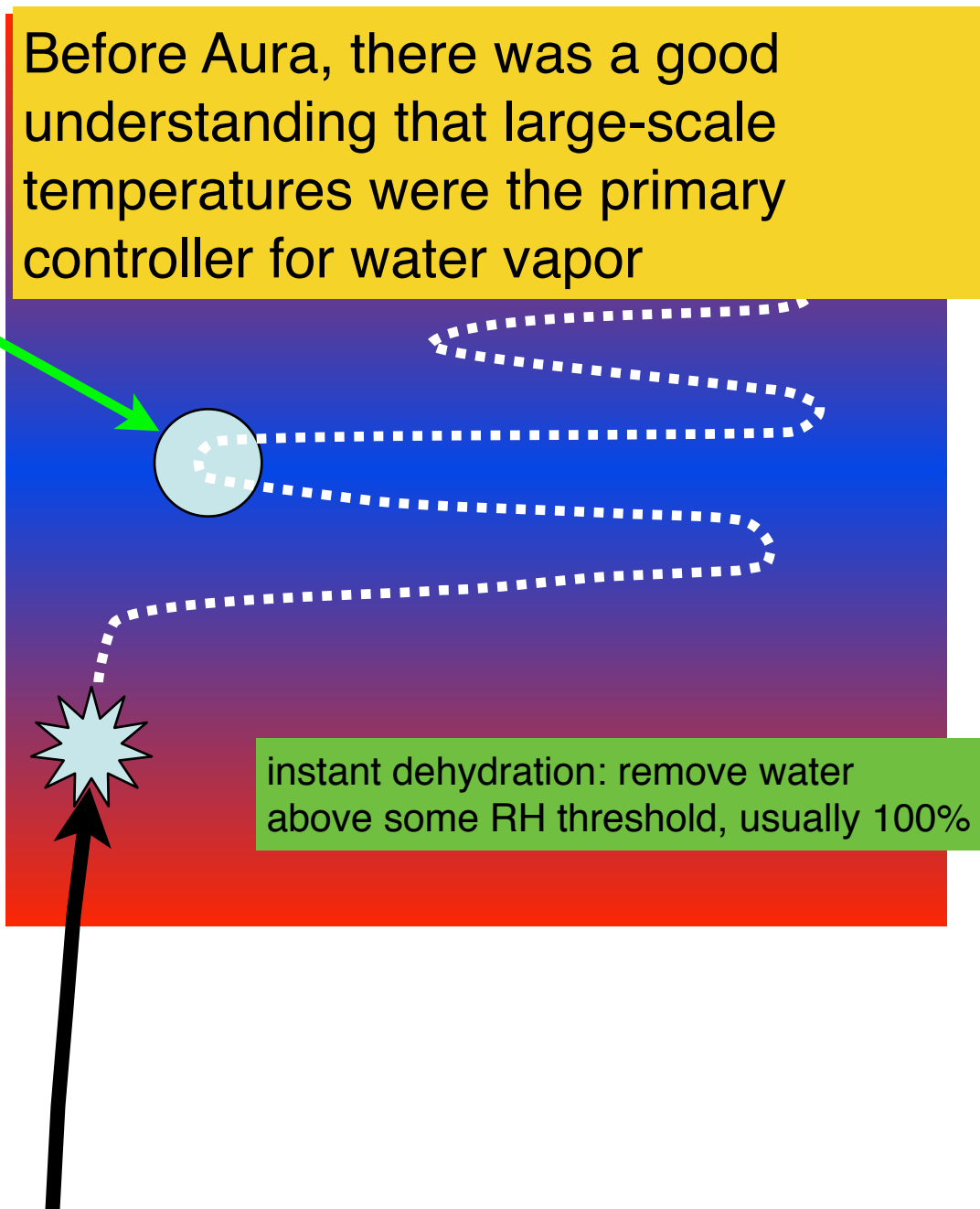
Before Aura, there was a good understanding that large-scale temperatures were the primary controller for water vapor

cold temperature
generate clouds

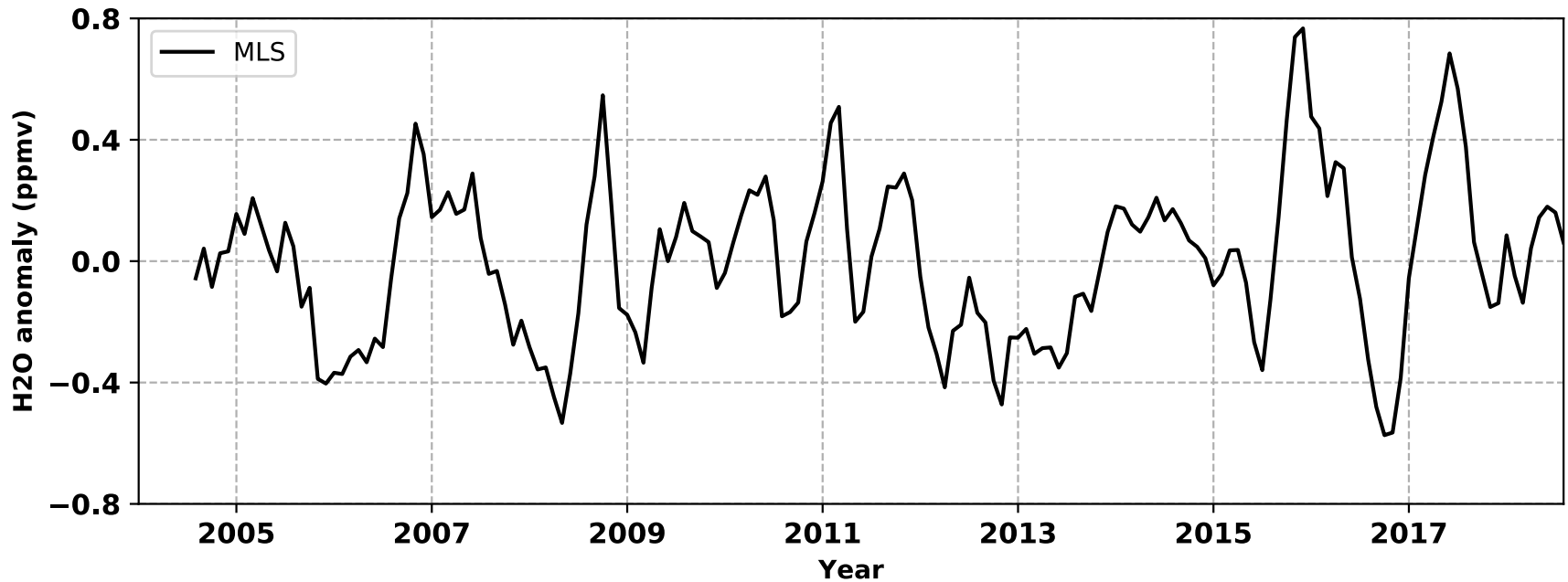
380 K

355 K

instant dehydration: remove water
above some RH threshold, usually 100%

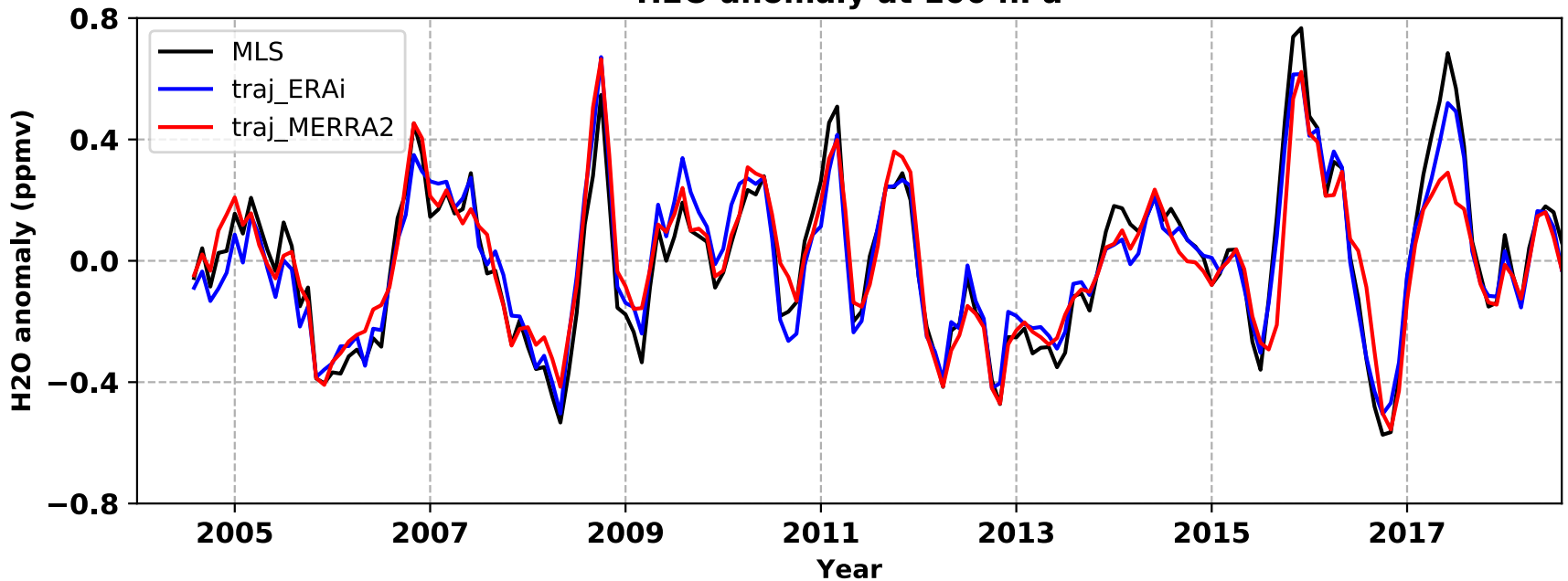


monthly avg. MLS V4; tropical average (25N-25S)
100 hPa

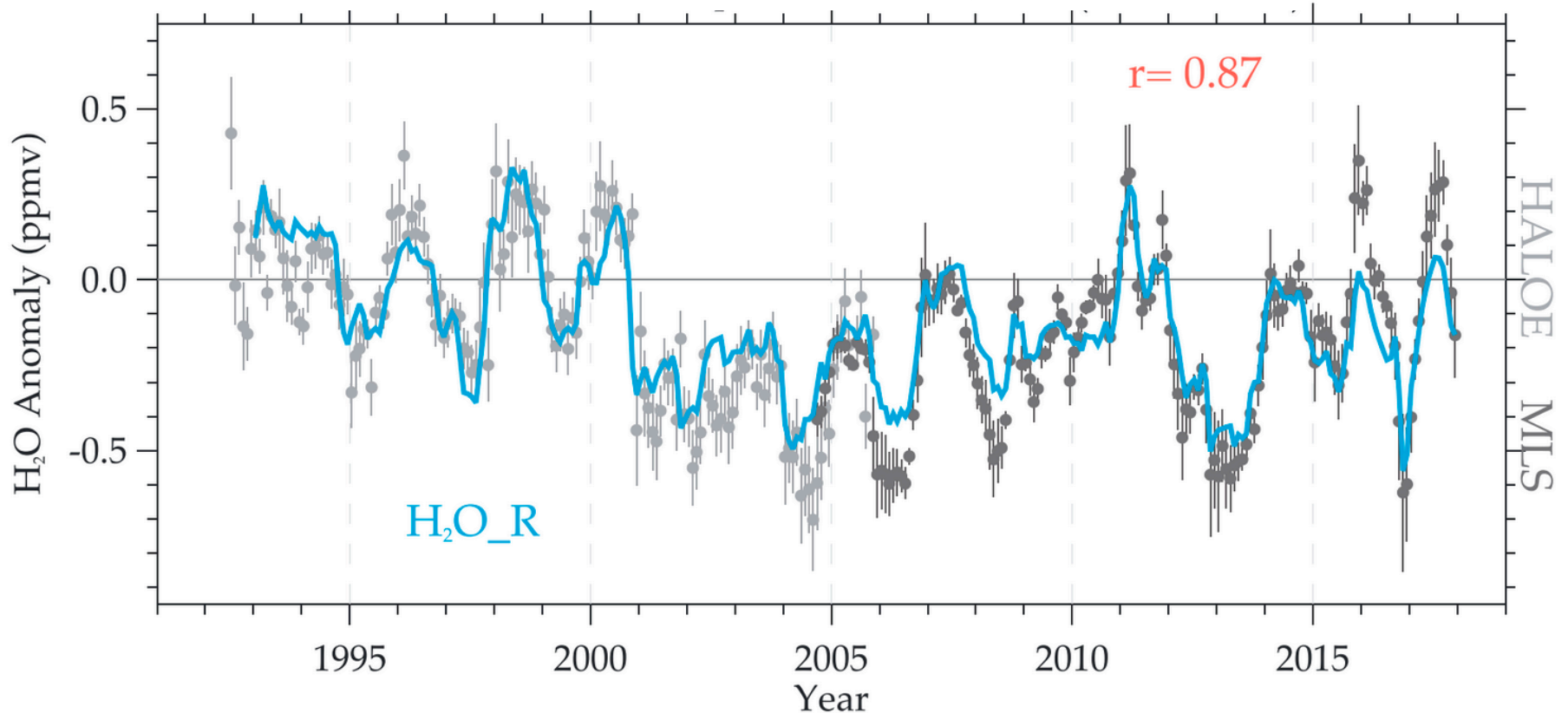


monthly avg. MLS V4 vs. trajectory models

H2O anomaly at 100 hPa



combined HALOE+Aura MLS H₂O data set
60N-60S, 83 hPa, monthly anomalies



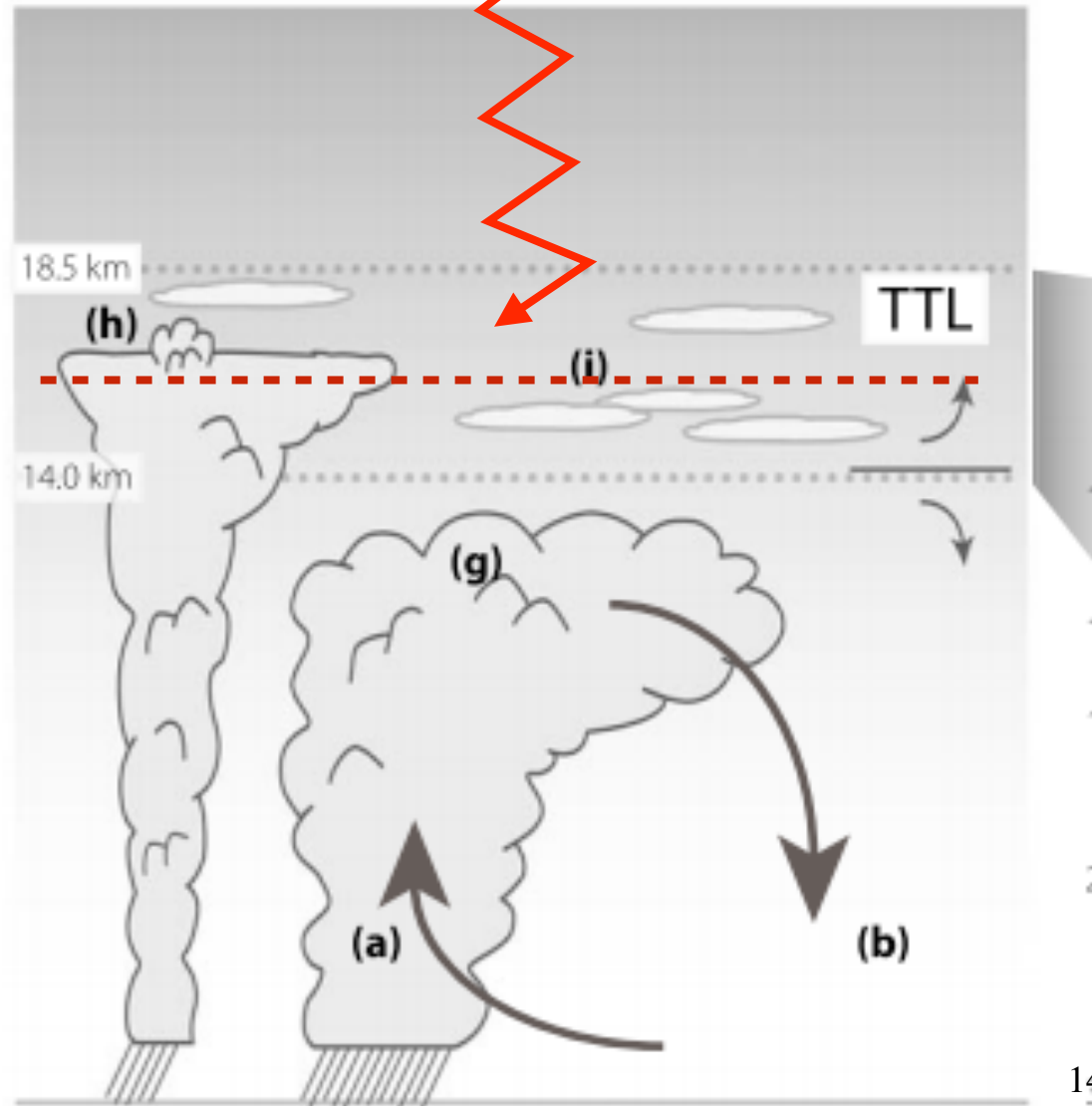
H₂O_R is based on variations in cold-point temperatures from radiosondes

Giorgetta & Bengtsson, JGR, 1999

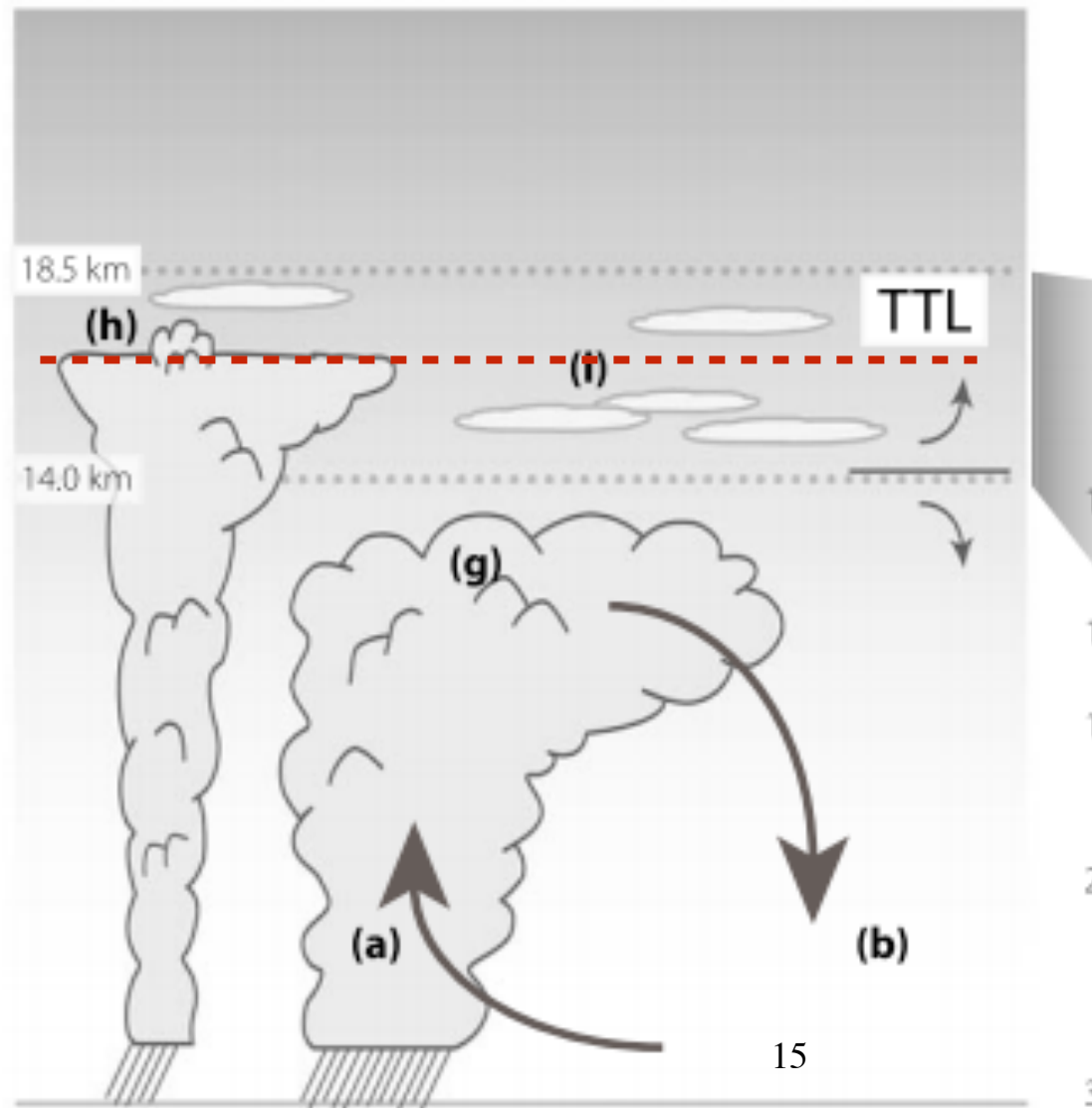
Geller et al., JAS, 2002

Randel et al., JGR, 2000

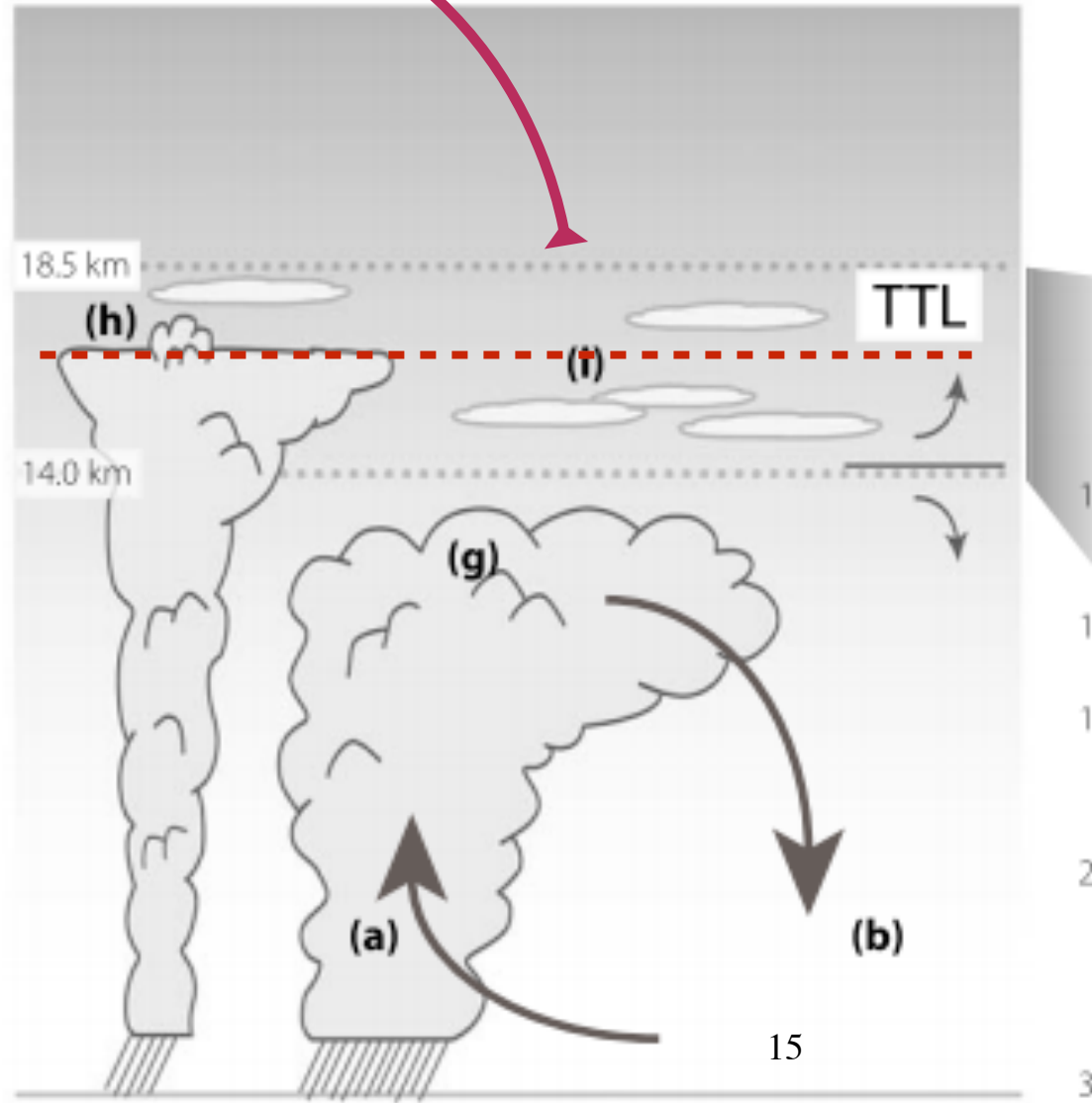
QBO



Yulaeva et al., JAS, 1994
Randel et al., JGR, 2006
Dhomse et al., ACP, 2008



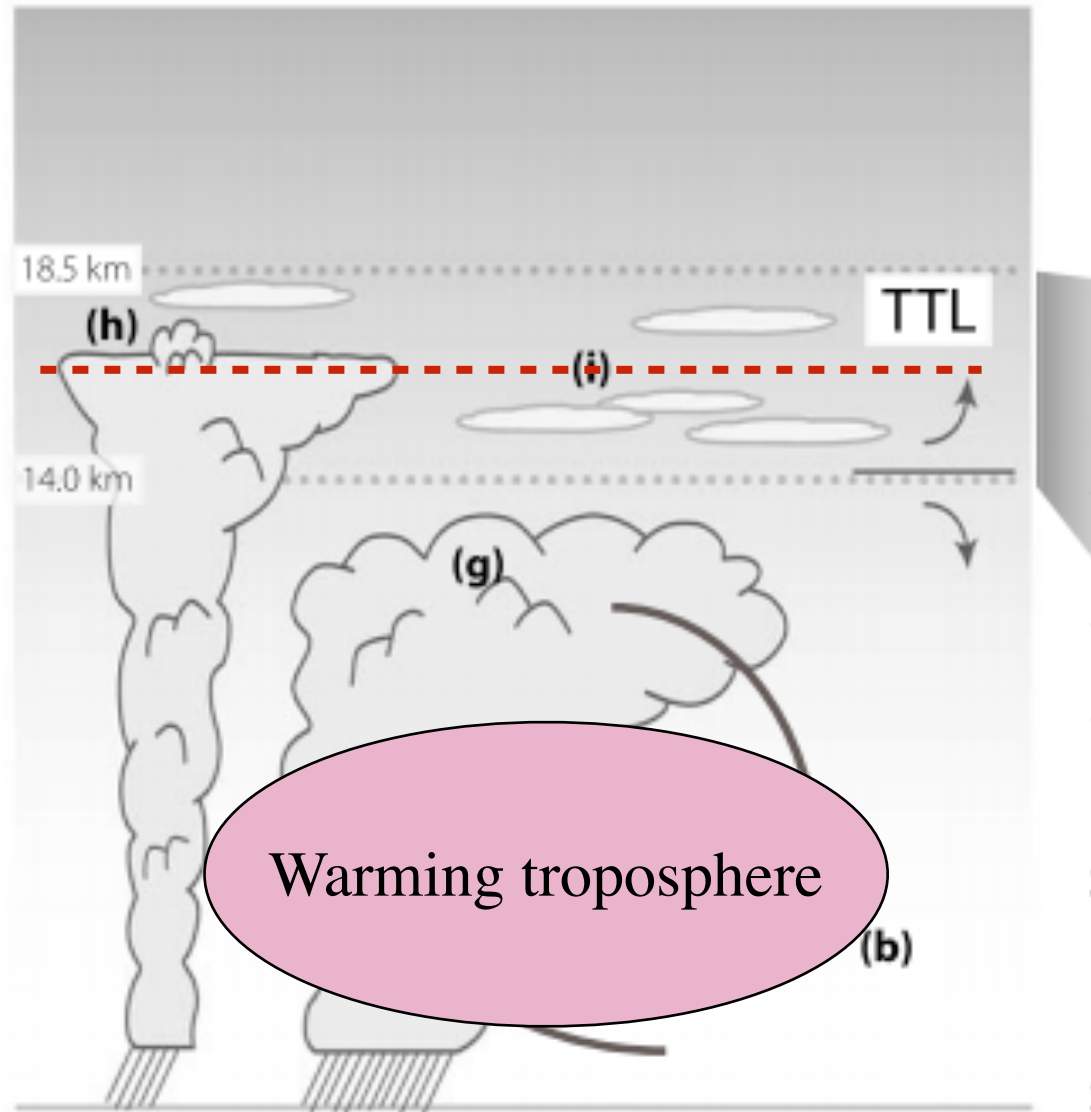
Enhanced



Yulaeva et al., JAS, 1994
Randel et al., JGR, 2006
Dhomse et al., ACP, 2008

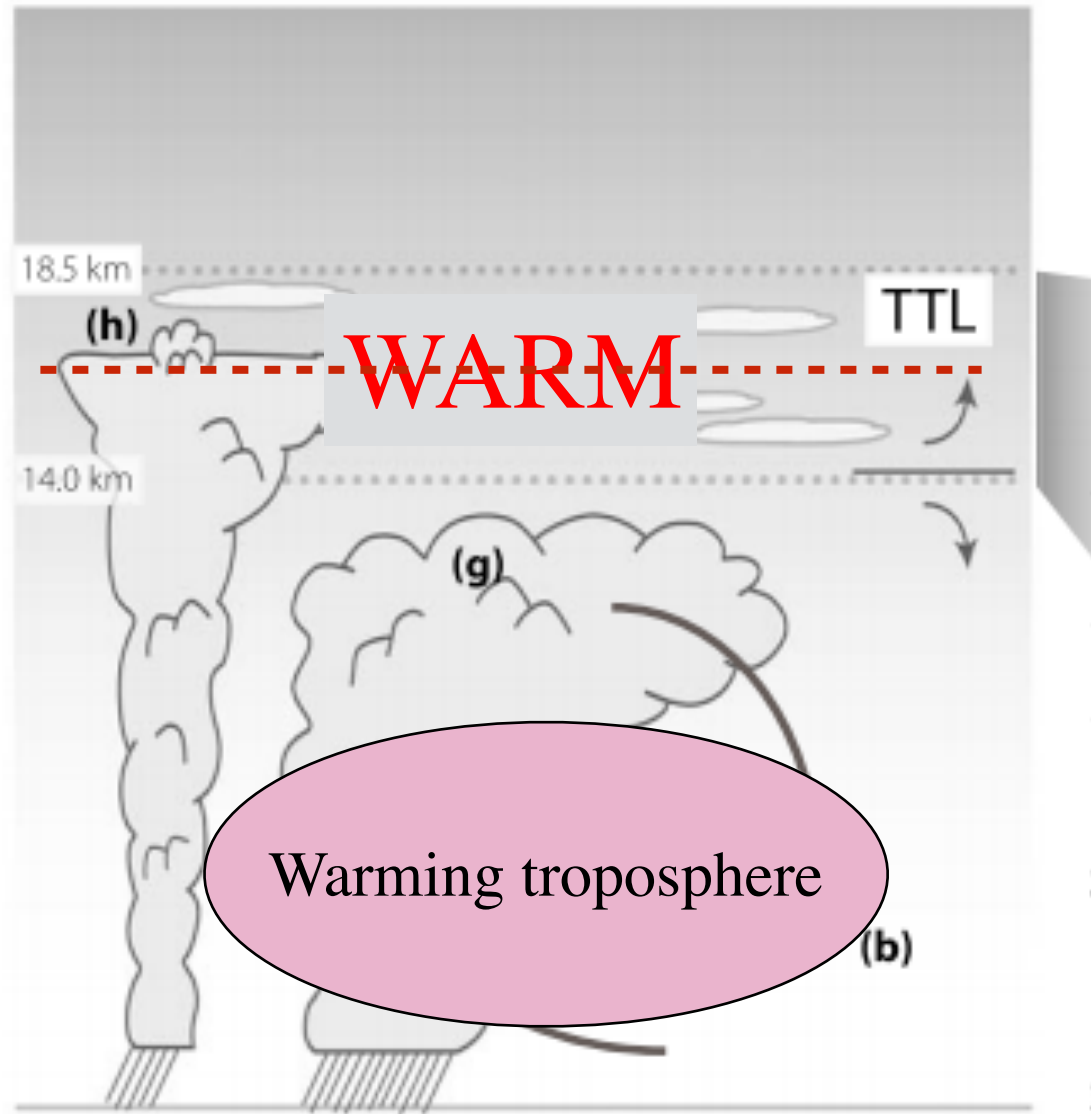
Geller et al., JAS, 2002

Davis et al., GRL, 2013



Geller et al., JAS, 2002

Davis et al., GRL, 2013



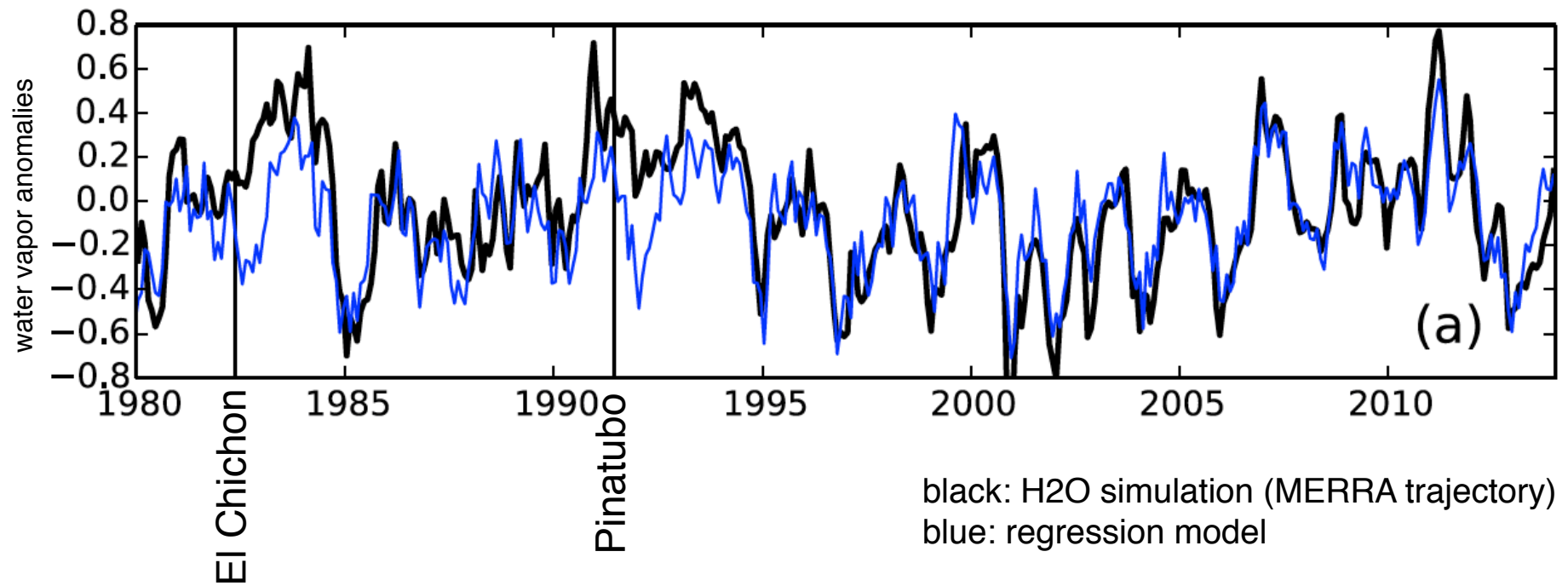
Multivariate linear least-squares fit:

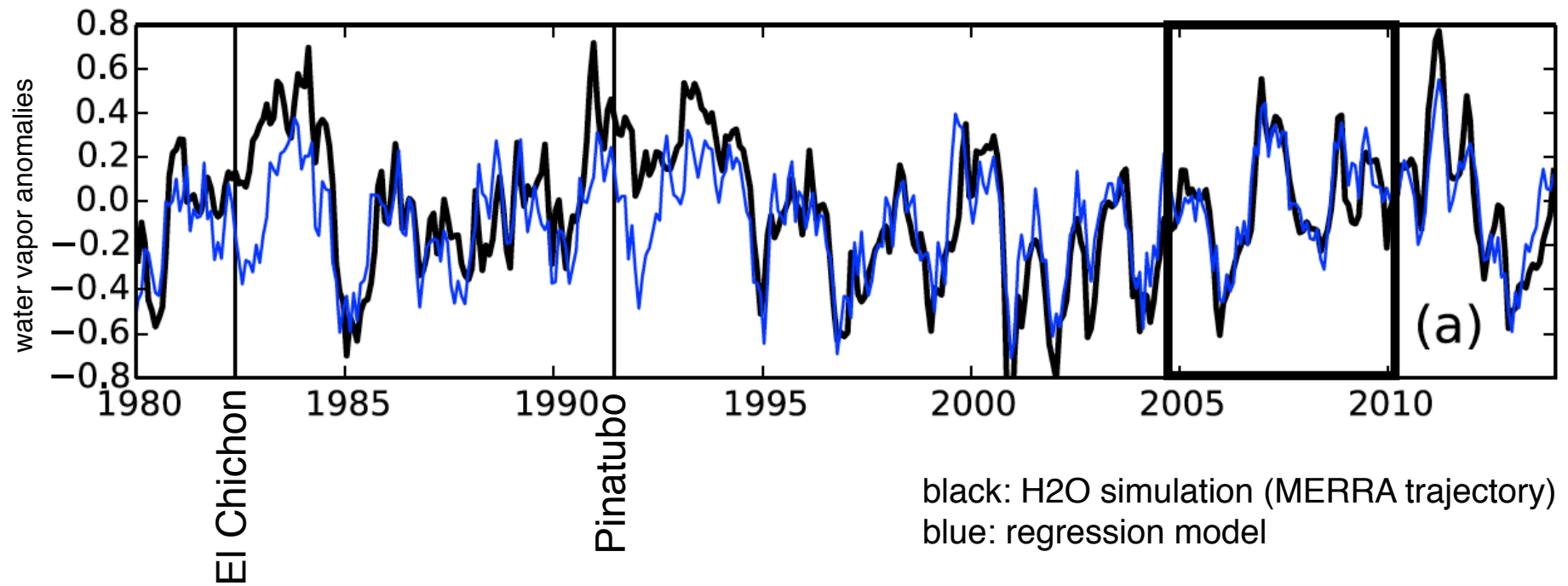
- $H_2O^* = a \text{ QBO} + b \text{ BD} + c \Delta T + r$

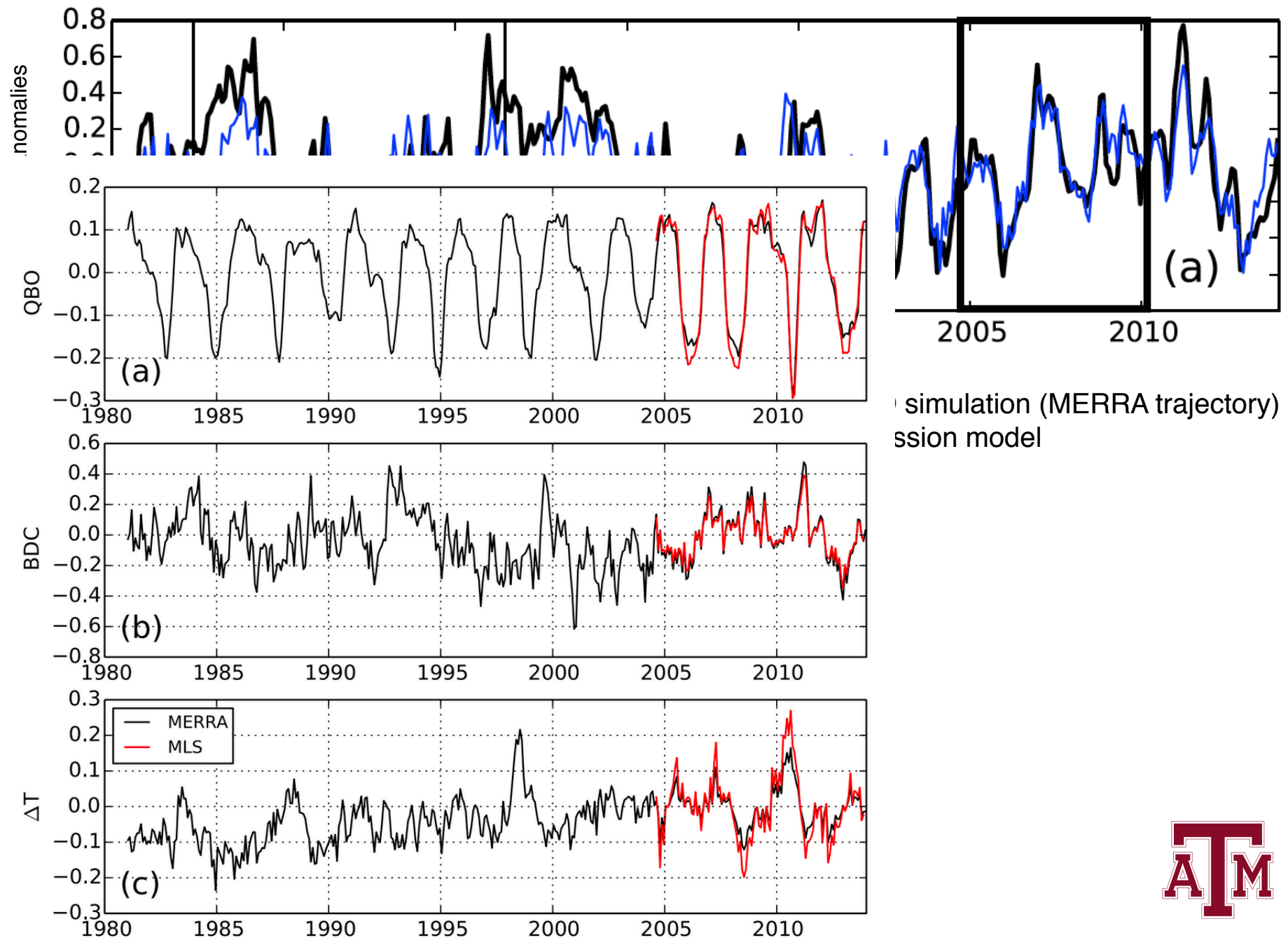


Multivariate linear least-squares fit:

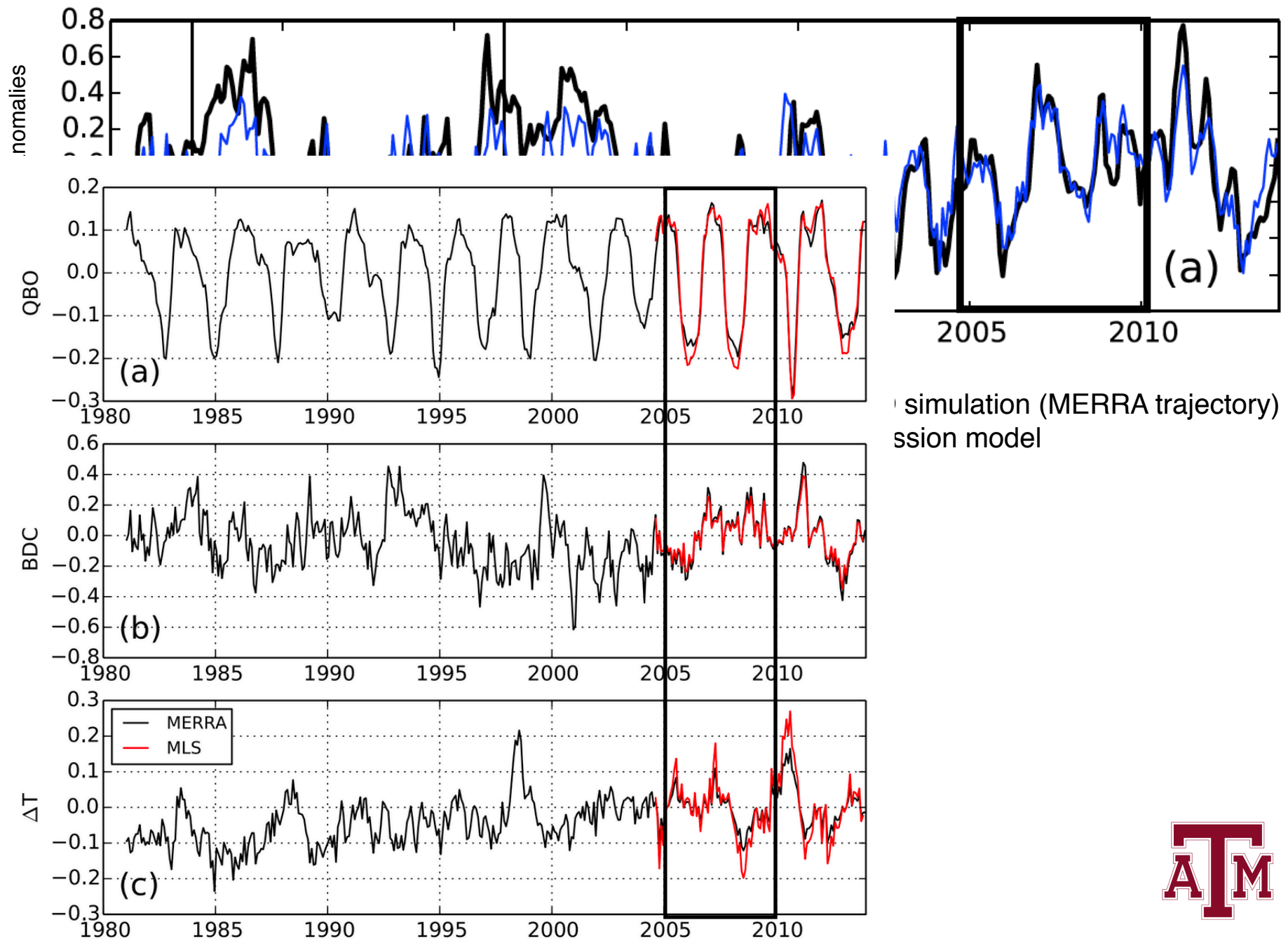
- $H_2O^* = a \text{ QBO} + b \text{ BD} + c \Delta T + r$
- QBO = QBO index
- BD = tropical avg. 82-hPa heating rate anomaly
- ΔT = tropical tropospheric temperature anomaly

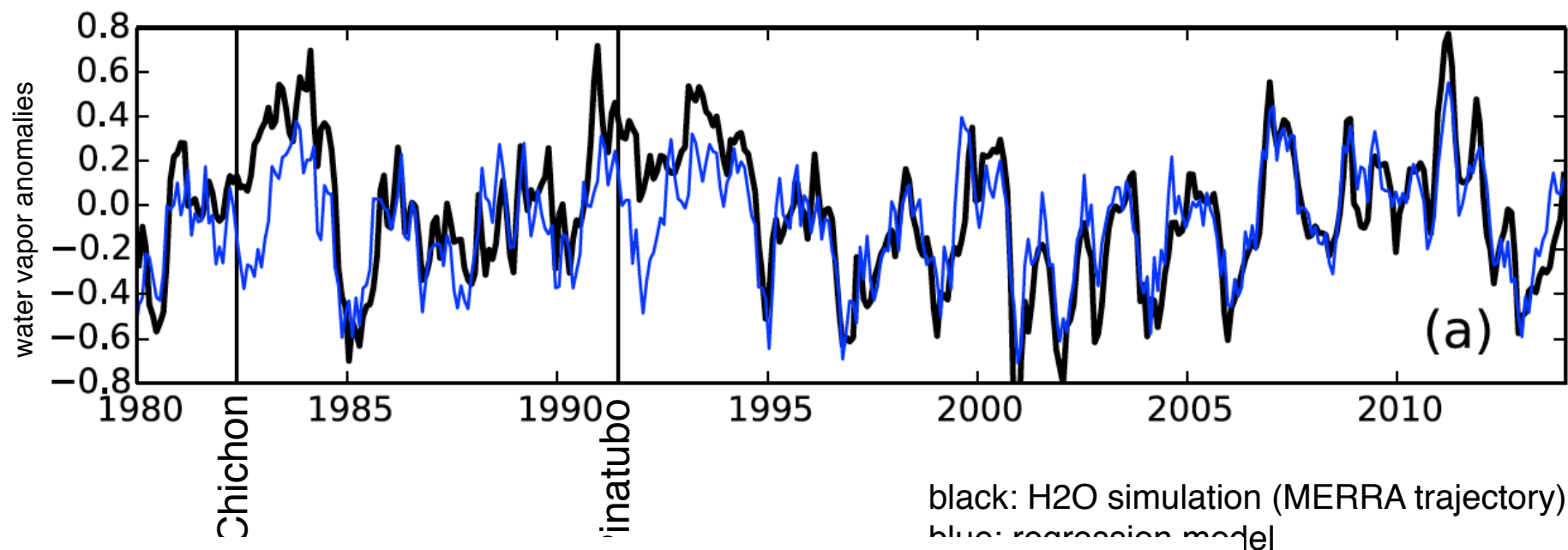






simulation (MERRA trajectory)
 ssion model





Contribution of different processes to changes in tropical lower-stratospheric water vapor in chemistry–climate models

Kevin M. Smalley¹, Andrew E. Dessler¹, Slimane Bekki², Makoto Deushi³, Marion Marchand², Olaf Morgenstern⁴, David A. Plummer⁵, Kiyotaka Shibata⁶, Yousuke Yamashita^{7,a}, and Guang Zeng⁴

¹Department of Atmospheric Sciences, Texas A&M, College Station, Texas, USA

²LATMOS, Institut Pierre Simon Laplace (IPSL), Paris, France

³Meteorological Research Institute, 1-1 Nagamine, Tsukuba, Ibaraki 305-0052, Japan

⁴National Institute of Water and Atmospheric Research (NIWA), Wellington, New Zealand

⁵Canadian Centre for Climate Modelling and Analysis, Environment and Climate Change Canada, Montreal, Canada

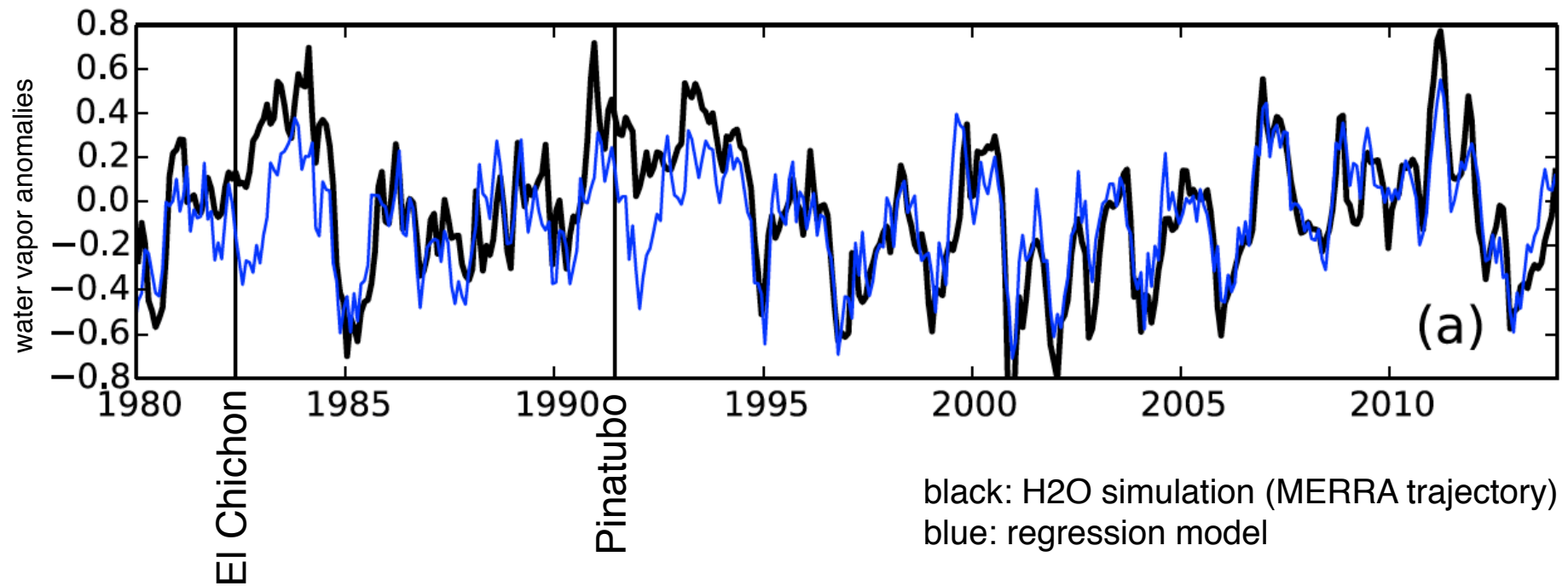
⁶School of Environmental Science and Engineering, Kochi University of Technology, Kami, Japan

⁷National Institute for Environmental Studies (NIES), Tsukuba, Japan

^anow at: Japan Agency for Marine–Earth Science and Technology (JAMSTEC), Yokohama, Japan

Received: 28 Oct 2016 – Discussion started: 08 Nov 2016 – Revised: 15 May 2017 – Accepted: 29 May 2017 – Published: 04 Jul 2017

Abstract. Variations in tropical lower-stratospheric humidity influence both the chemistry and climate of the atmosphere. We analyze tropical lower-stratospheric water vapor in 21st century simulations from 12 state-of-the-art chemistry–climate models (CCMs), using a linear regression model to determine the factors driving the trends and variability. Within CCMs, warming of the troposphere primarily drives the long-term trend in stratospheric humidity. This is partially offset in most CCMs by an increase in the strength of the Brewer–Dobson circulation, which tends to cool the tropical tropopause layer (TTL). We also apply the regression model to individual decades from the 21st century CCM runs and compare them to a regression of a decade of observations. Many of the CCMs, but not all, compare well with these observations, lending credibility to their predictions. One notable deficiency is that most CCMs underestimate the impact of the quasi-biennial oscillation on lower-stratospheric water vapor. Our analysis provides a new and potentially superior way to evaluate model trends in lower-stratospheric humidity.

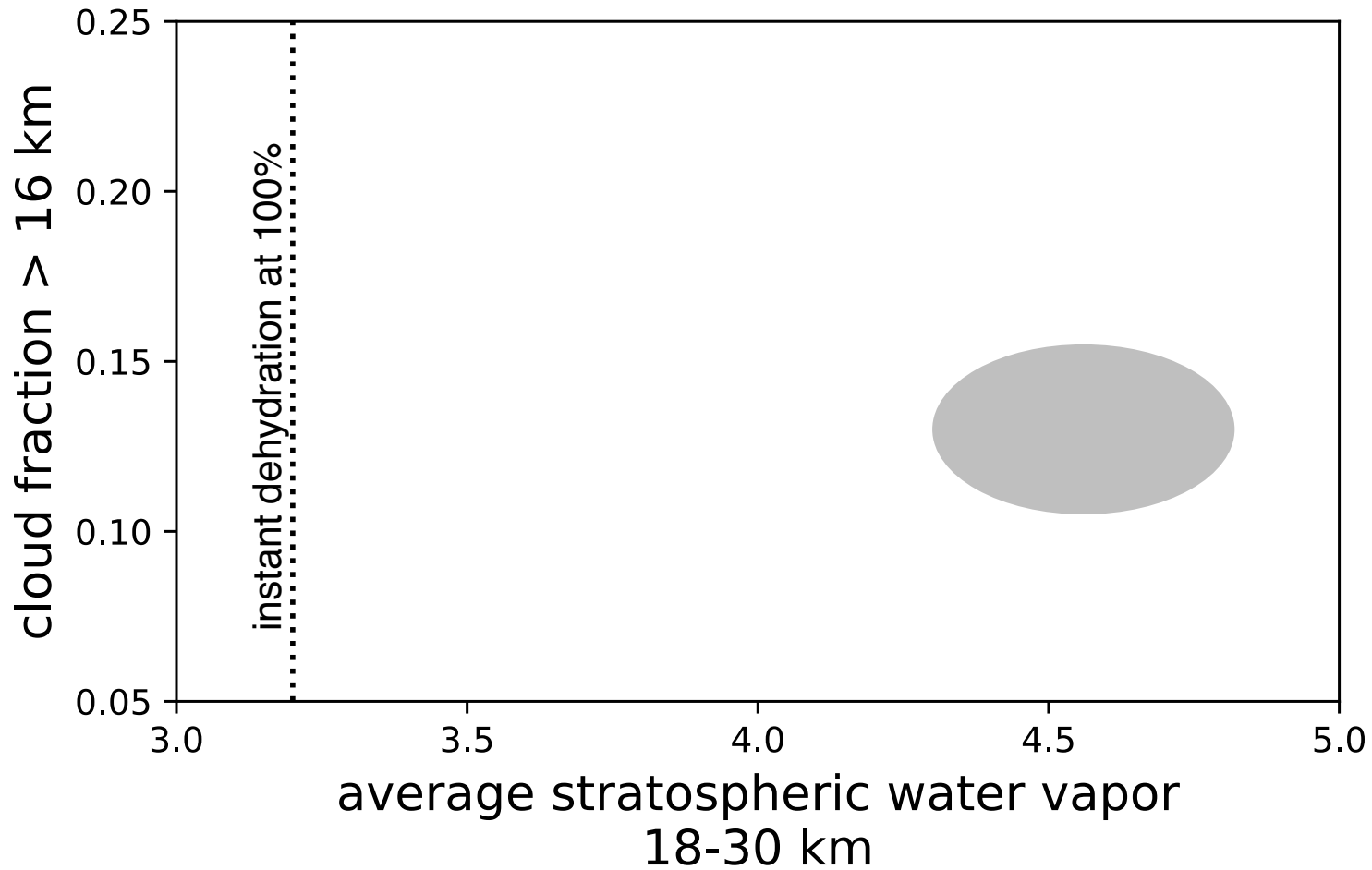


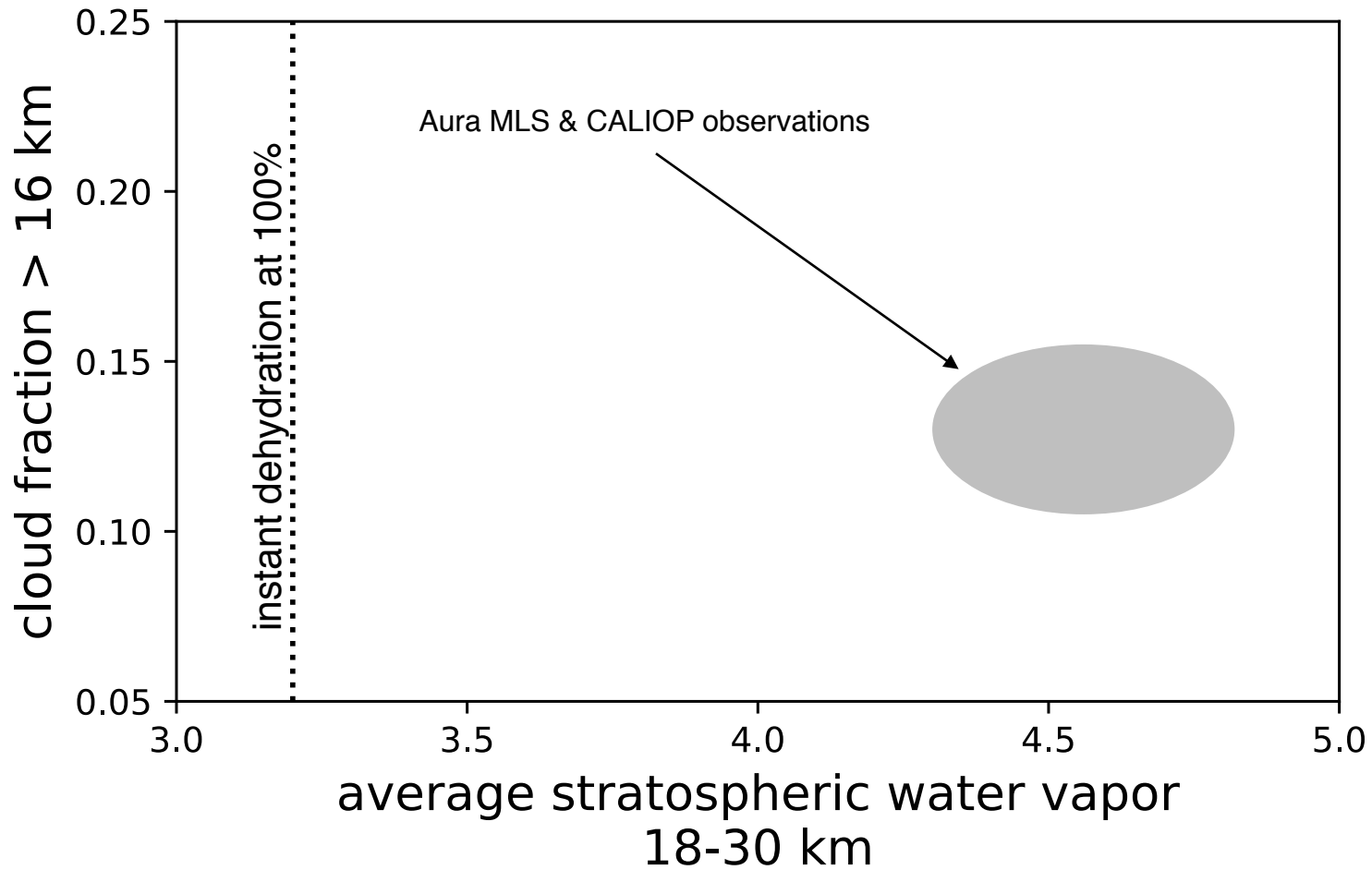
we see little trend in H₂O
since the early 1980s

also Heggelin et al., Nat. Geosci., 2014

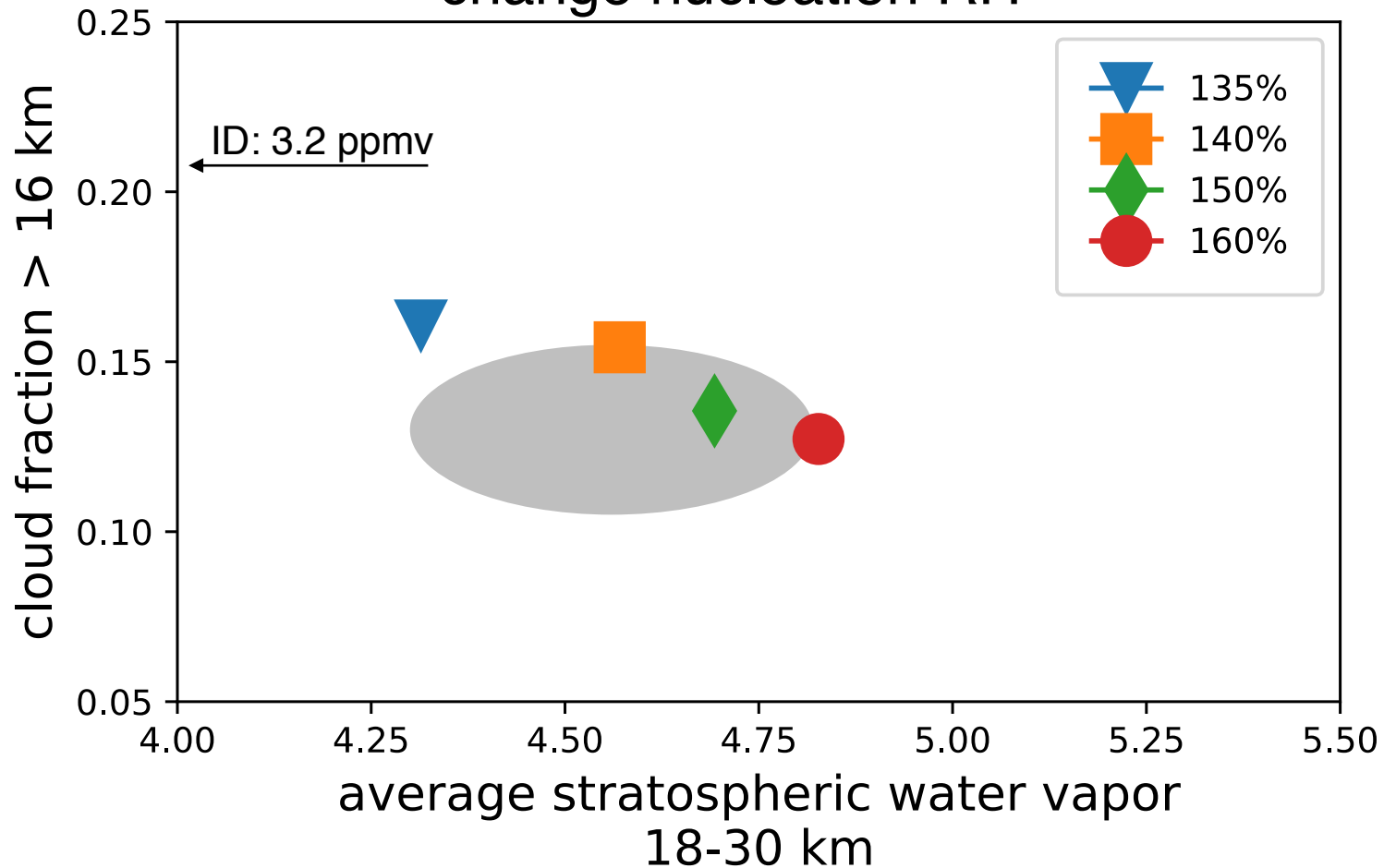
Aura advances in stratospheric water vapor

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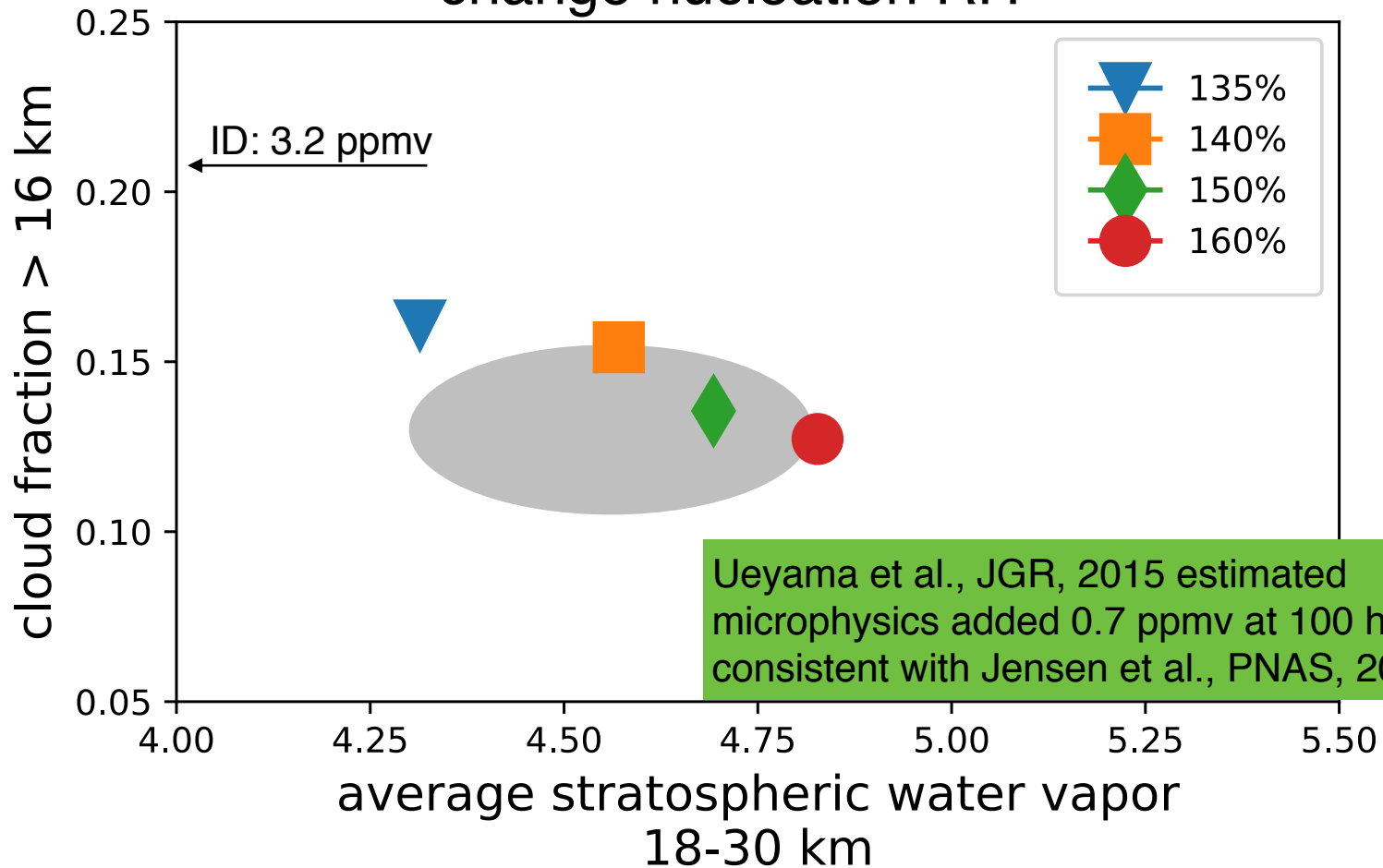




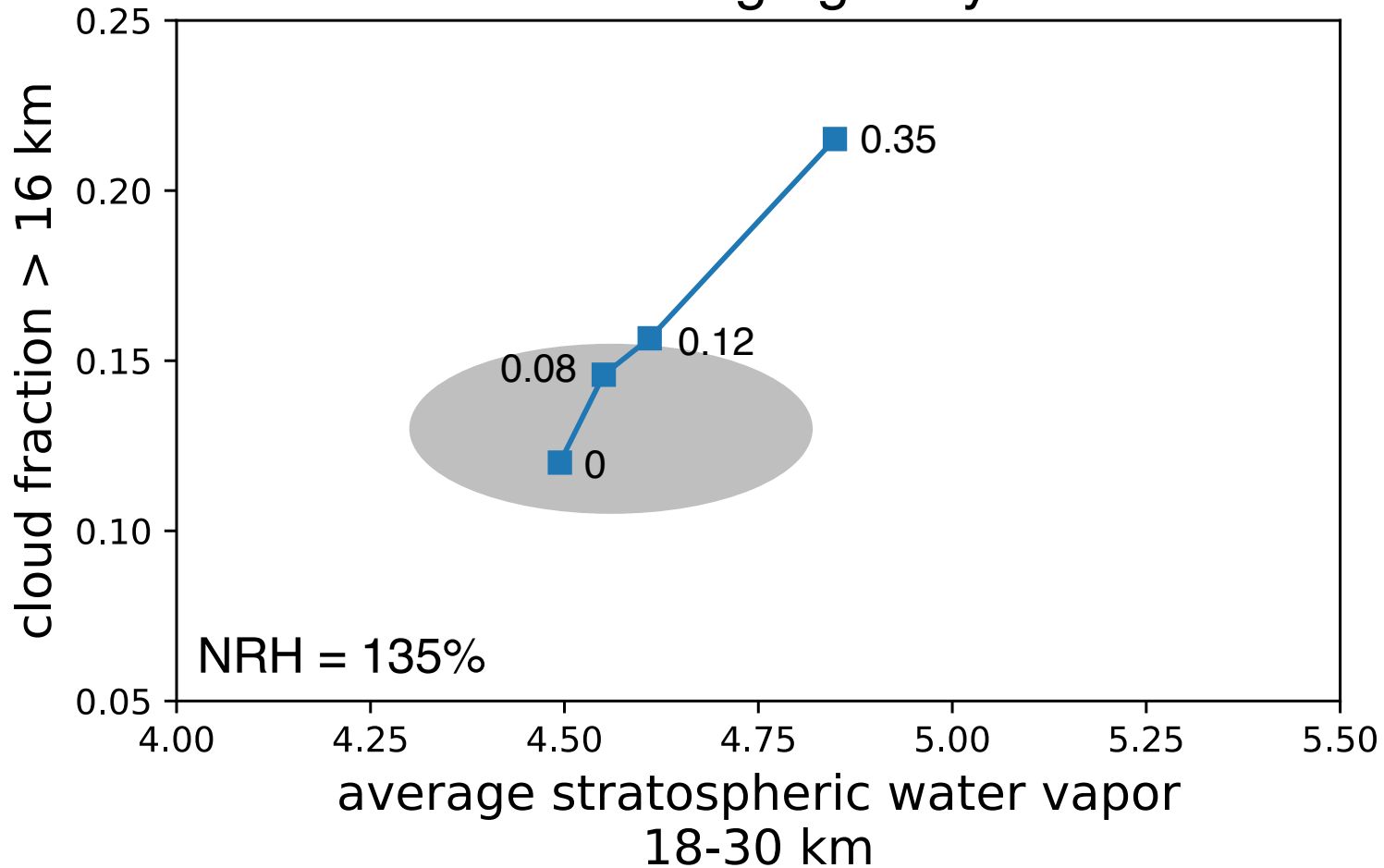
trajectory model + cloud model change nucleation RH



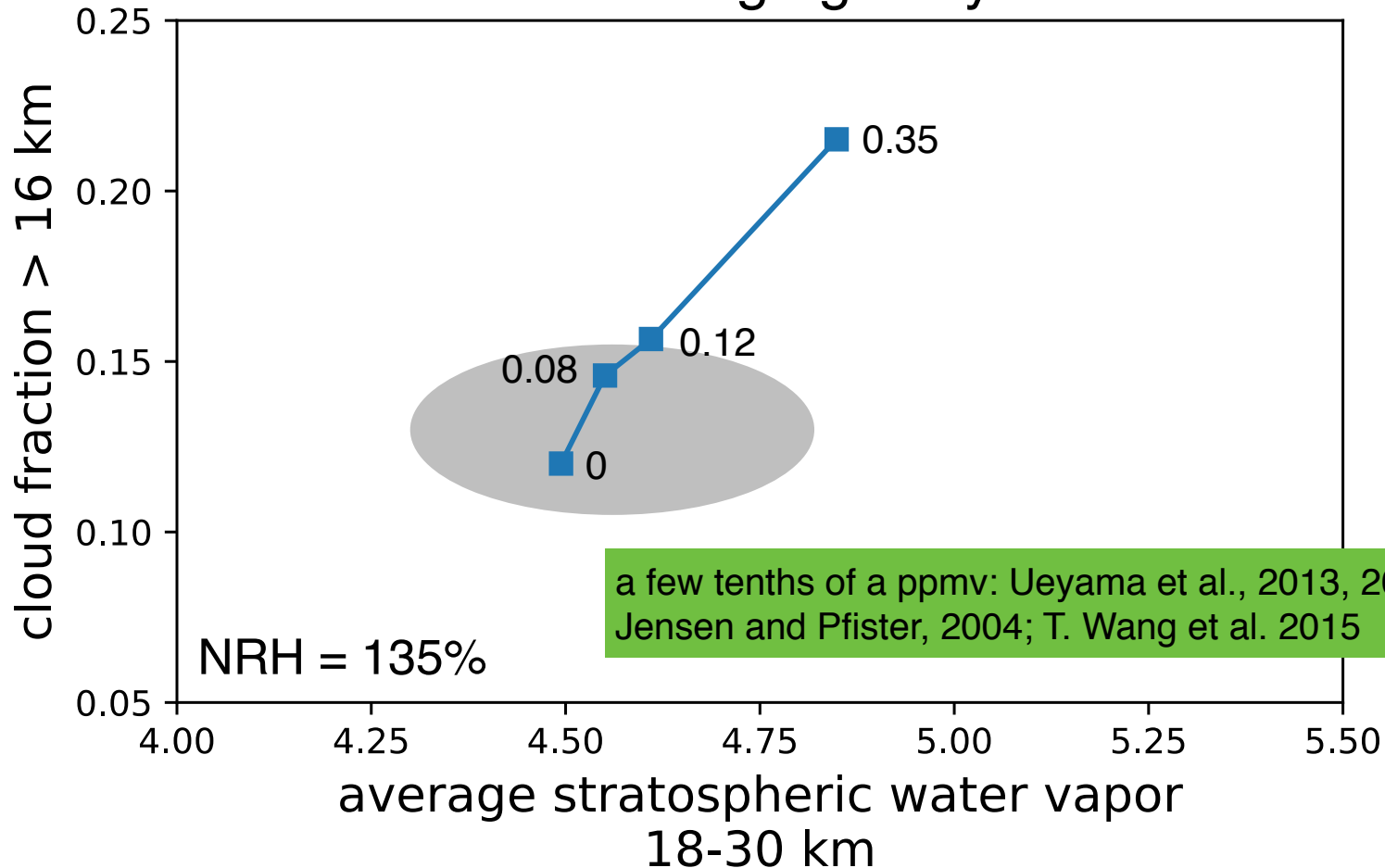
trajectory model + cloud model change nucleation RH



trajectory model + cloud model
unresolved change gravity waves



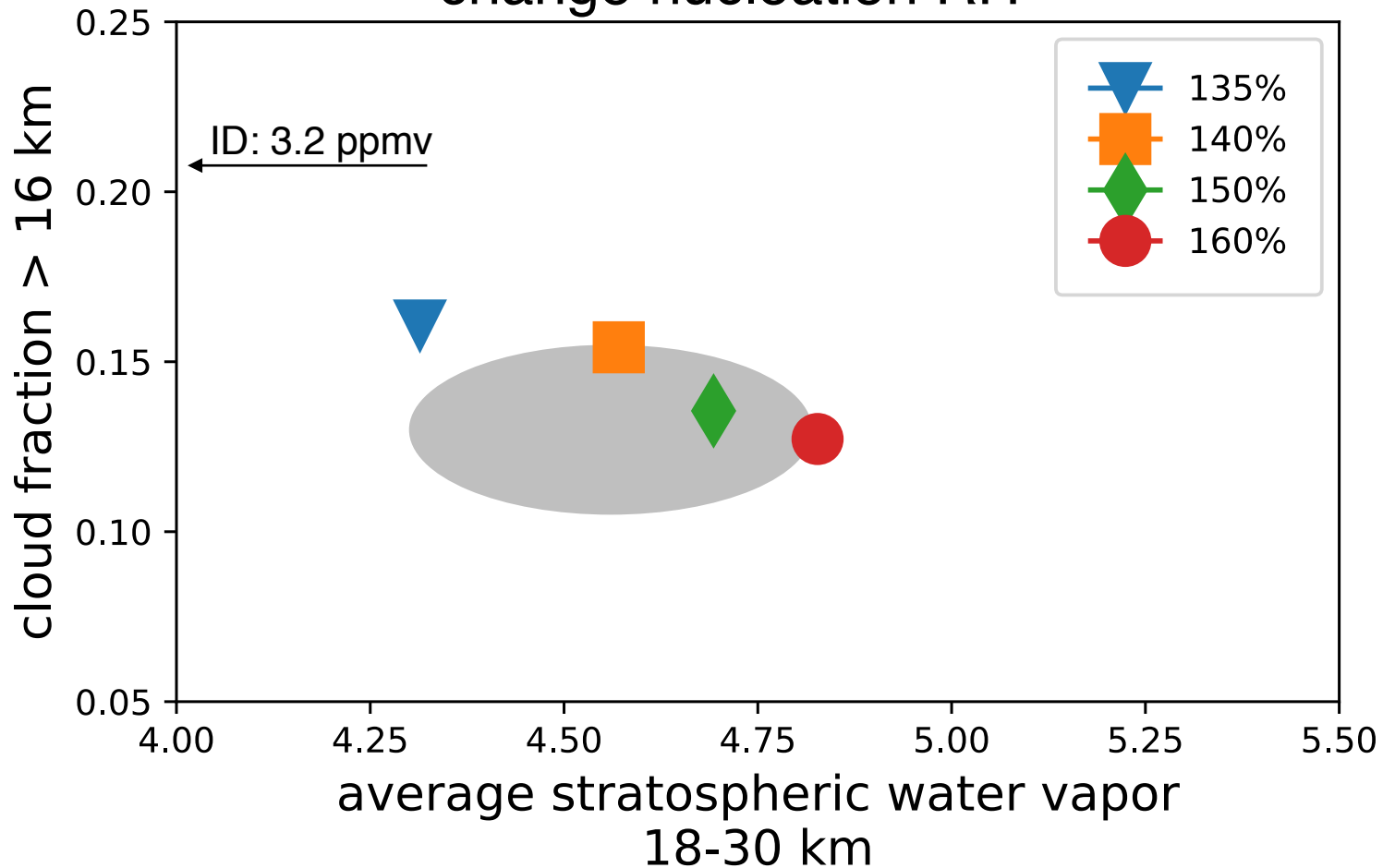
trajectory model + cloud model
unresolved change gravity waves



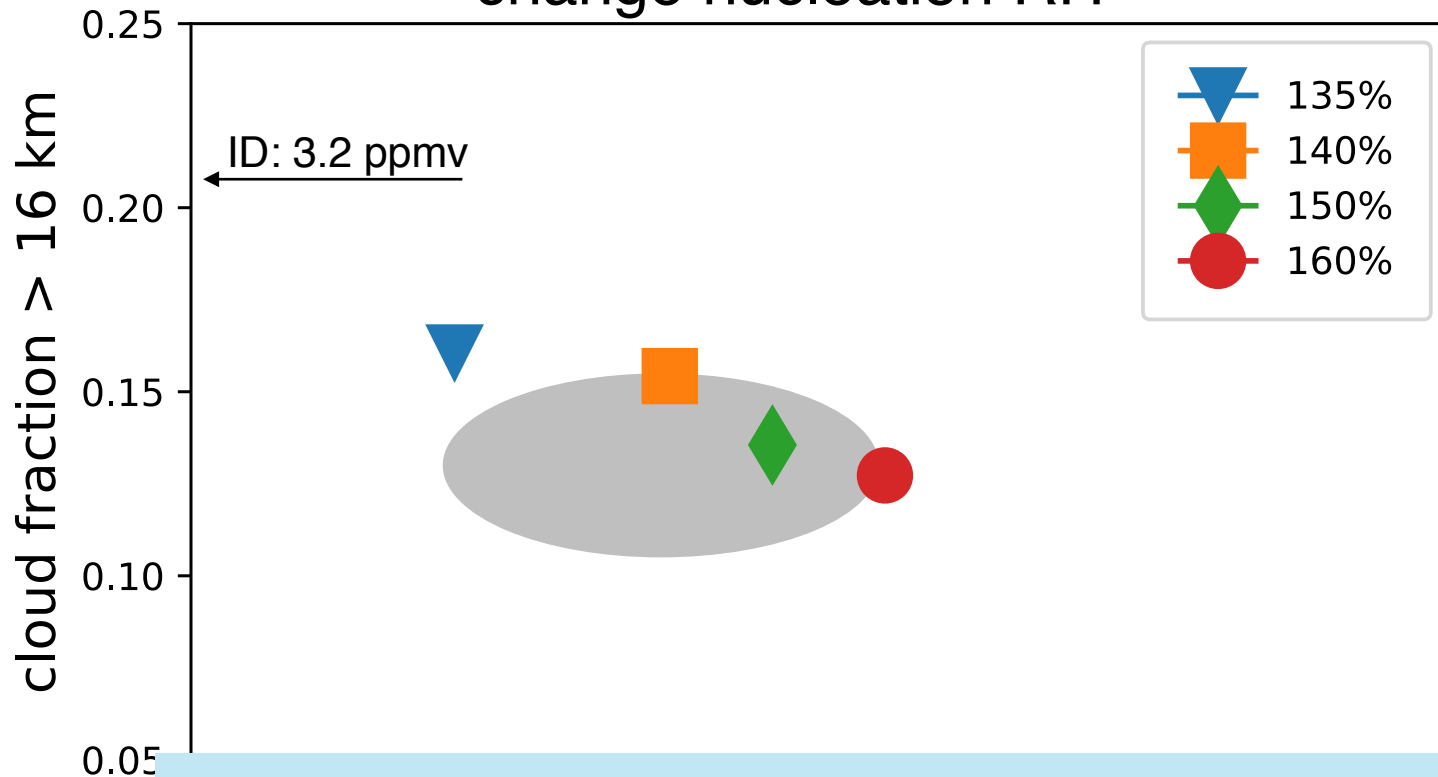
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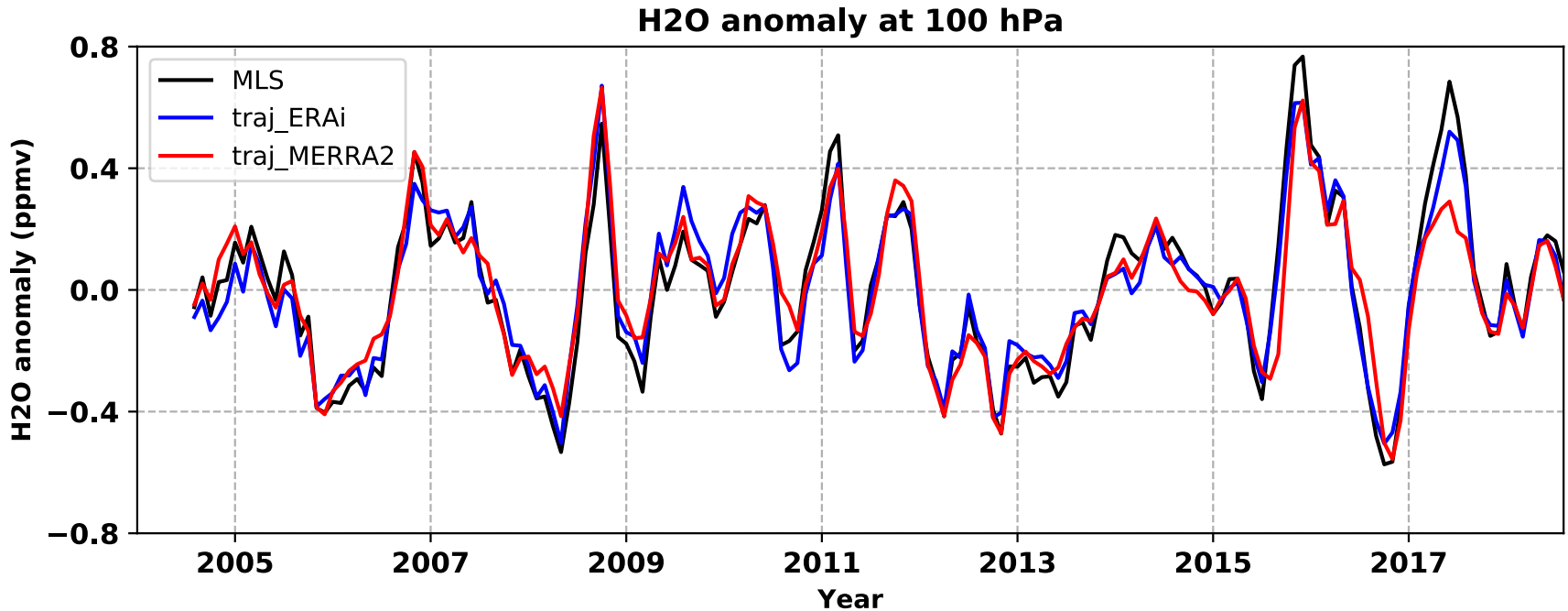


trajectory model + cloud model change nucleation RH



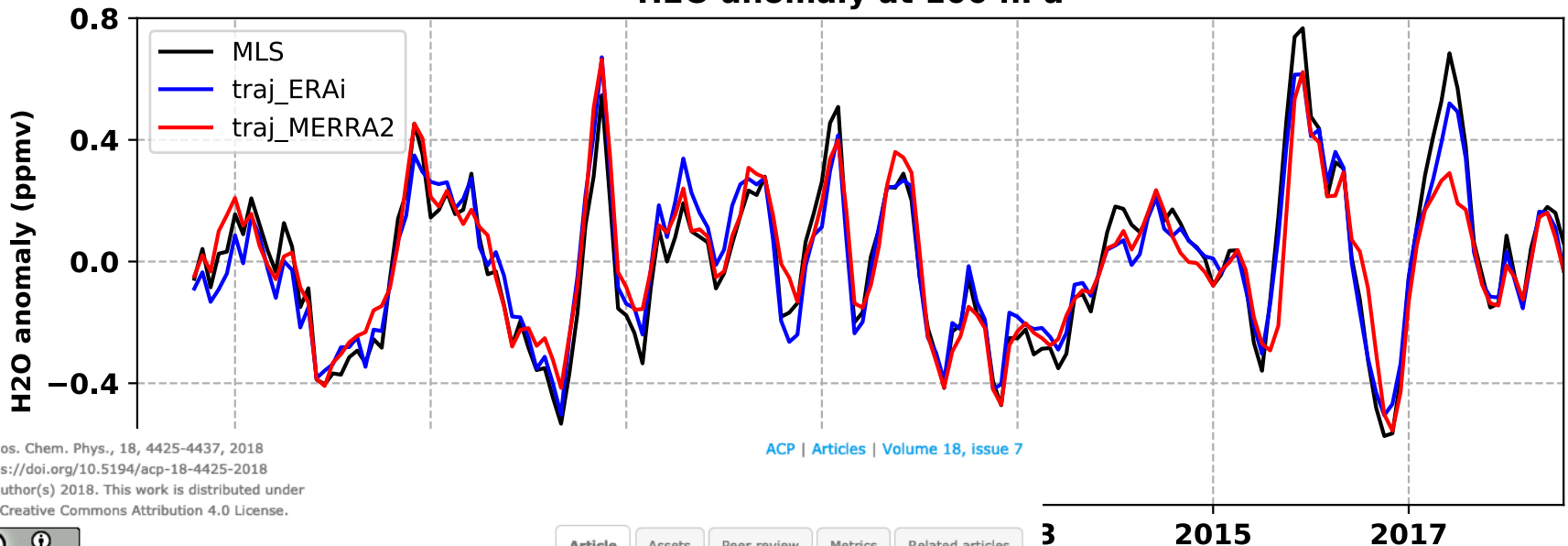
- Schoeberl et al. 2018: convection increases H_2O averaged between 18-30 km by $< 2\%$
- Ueyama et al. 2018: convection increases H_2O at 100 hPa by 15% during NH summer

interannual variability in convection drives small changes in 100-hPa water vapor



interannual variability in convection drives small changes in 100-hPa water vapor

H2O anomaly at 100 hPa



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ACP | Articles | Volume 18, Issue 7



Research article

03 Apr 2018

Effects of convective ice evaporation on interannual variability of tropical tropopause layer water vapor

Hao Ye, Andrew E. Dessler , and Wandu Yu

Department of Atmospheric Sciences, Texas A&M University, College Station, TX, USA

Received: 12 Oct 2017 – Discussion started: 25 Oct 2017 – Revised: 12 Feb 2018 – Accepted: 25 Feb 2018 – Published: 03 Apr 2018

Abstract

[Back to top](#)

Water vapor interannual variability in the tropical tropopause layer (TTL) is investigated using satellite observations and model simulations. We break down the influences of the Brewer–Dobson circulation (BDC), the quasi-biennial oscillation (QBO), and the tropospheric temperature (ΔT) on TTL water vapor as a function of latitude and longitude using a two-dimensional multivariate linear regression. This allows us to examine the spatial distribution of the impact of each process on TTL water vapor. In agreement with expectations, we find that the impacts from the BDC and QBO act on TTL water vapor by changing TTL temperature. For ΔT , we find that TTL temperatures alone cannot explain the influence. We hypothesize a moistening role for the evaporation of convective ice from increased deep convection as the troposphere warms. Tests using a chemistry–climate model, the Goddard Earth Observing System Chemistry Climate Model (GEOSCCM), support this hypothesis.

<https://doi.org/10.5194/acp-2019-302>

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Abstract

Discussion

Metrics

Submitted as: research article

29 Apr 2019

Impact of convectively lofted ice on the seasonal cycle of tropical lower stratospheric water vapor

Xun Wang¹, Andrew E. Dessler¹, Mark R. Schoeberl², Wandu Yu¹, and Tao Wang³

¹Department of Atmospheric Sciences, Texas A&M University, College Station, TX, USA

²Science and Technology Corporation, Columbia, MD, USA

³University of Maryland, College Park, MD, USA

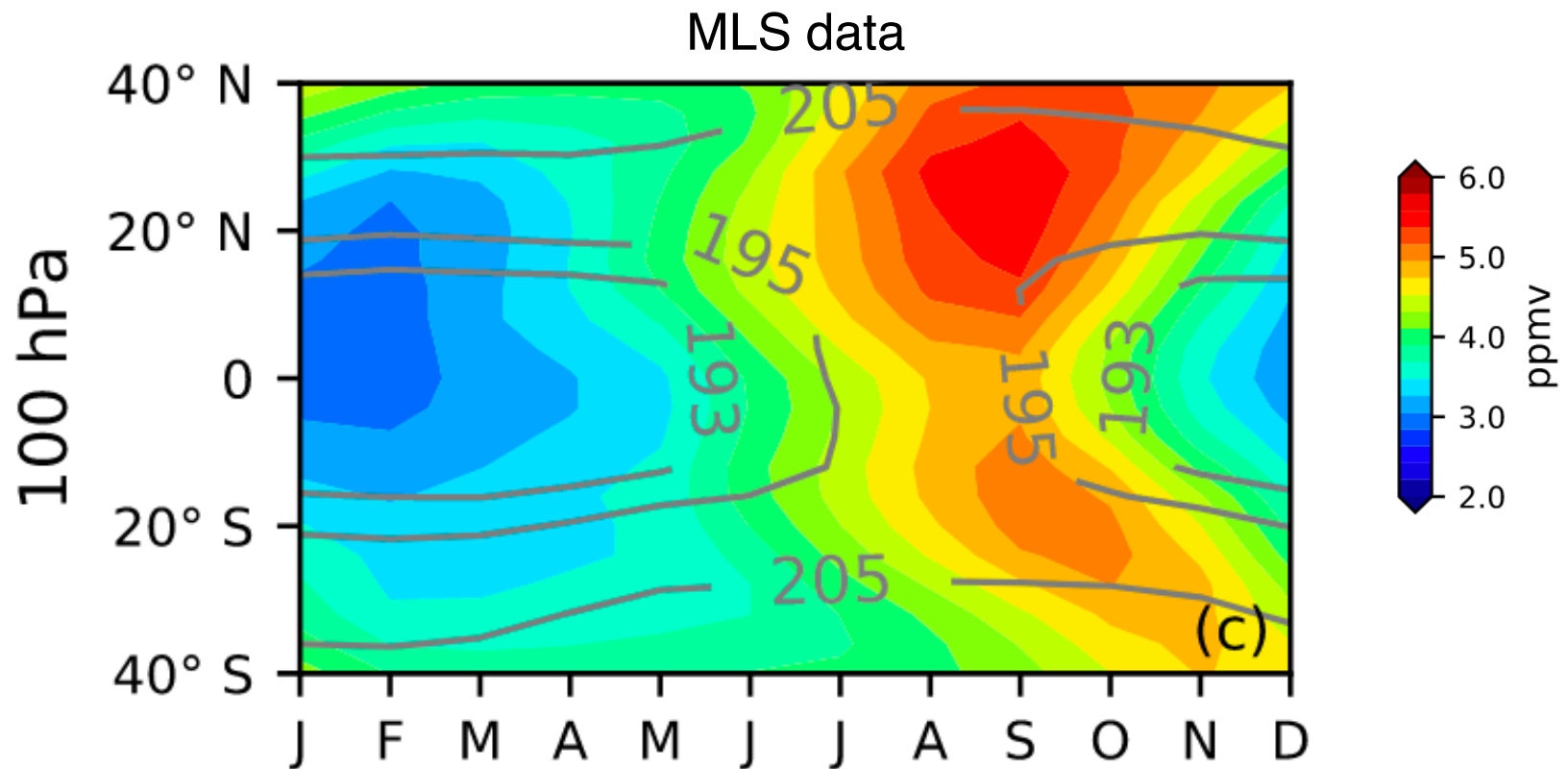
Review status

This discussion paper is a preprint. It is a manuscript under review for the journal Atmospheric Chemistry and Physics (ACP).

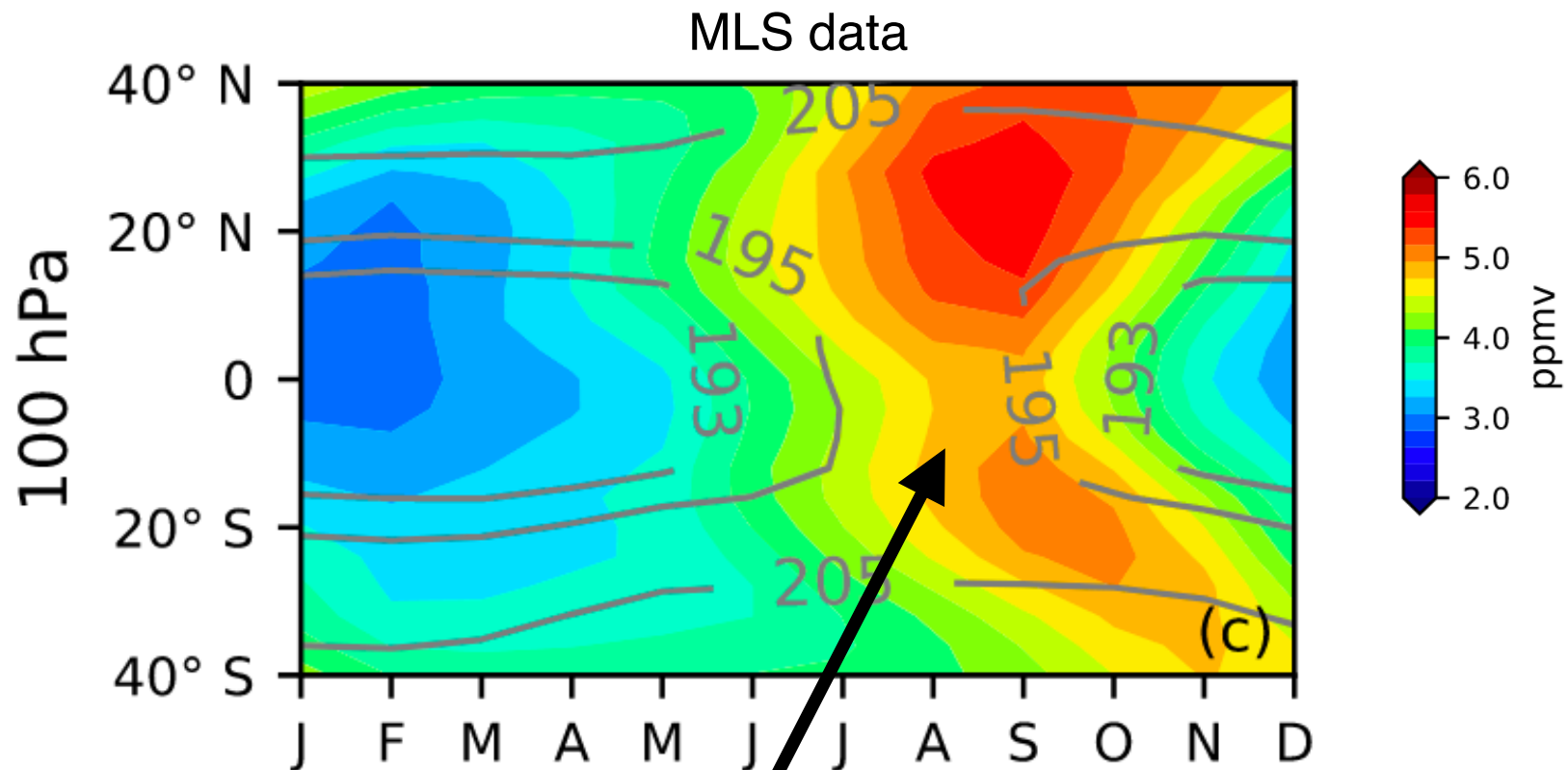
Received: 29 Mar 2019 – Accepted for review: 25 Apr 2019 – Discussion started: 29 Apr 2019

Abstract. We use a forward Lagrangian trajectory model to diagnose mechanisms that produce the tropical lower stratospheric (LS) water vapor seasonal cycle observed by the Microwave Limb Sounder (MLS) and reproduced by the Goddard Earth Observing System Chemistry Climate Model (GEOSCCM) in the tropical tropopause layer (TTL). We confirm in both the MLS and GEOSCCM that the seasonal cycle of water vapor is primarily determined by the seasonal cycle of TTL temperatures. However, we find that the seasonal cycle of temperature predicts a smaller seasonal cycle of LS water vapor between 10° N–40° N than observed by MLS. We show that including evaporation of convectively lofted ice in the trajectory model increases the simulated maximum value in the 10° N–40° N water vapor seasonal cycle by 1.9 ppmv (47 %) and increases the seasonal amplitude by 1.26 ppmv (123 %), which improves the prediction of LS water vapor annual cycle. We conclude that the moistening effect from convective ice evaporation in the TTL plays a key role regulating and maintaining the tropical LS water vapor seasonal cycle. Most of the convective moistening in the 10° N–40° N range comes from convective ice evaporation occurring at the same latitudes. A small contribution to the moistening comes from convective ice evaporation occurring between 10° S–10° N. Within 10° N–40° N, the Asian monsoon region is the most important region for convective ice evaporation and convective moistening during boreal summer and autumn.

How to cite: Wang, X., Dessler, A. E., Schoeberl, M. R., Yu, W., and Wang, T.: Impact of convectively lofted ice on the seasonal cycle of tropical lower stratospheric water vapor, Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2019-302>, in review, 2019.

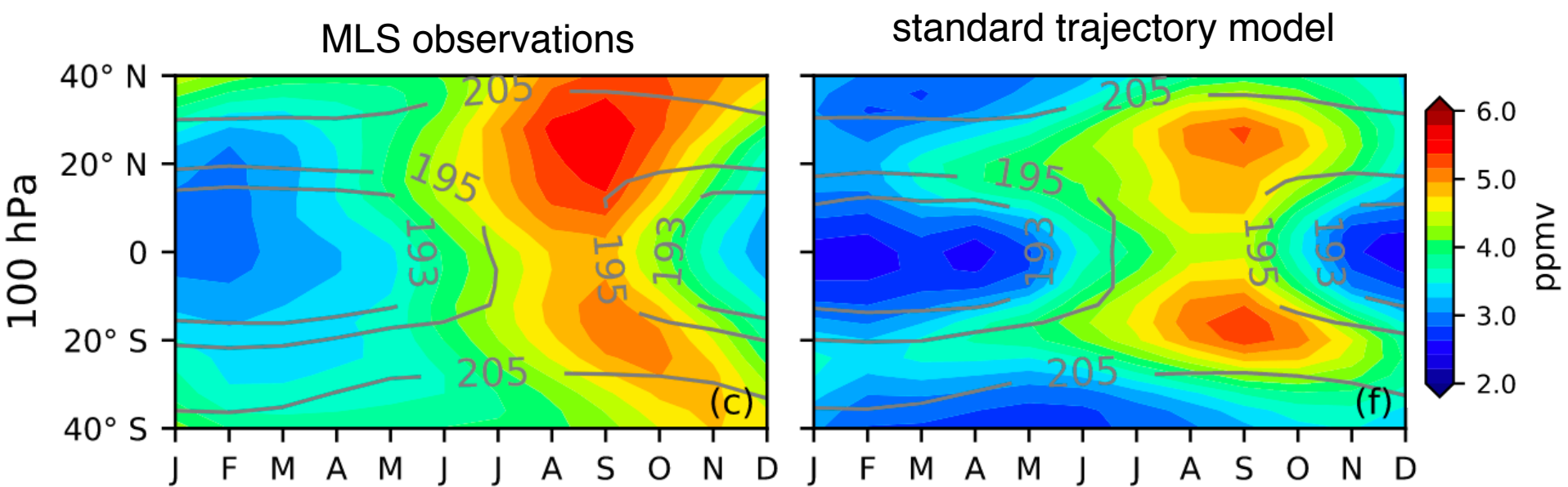


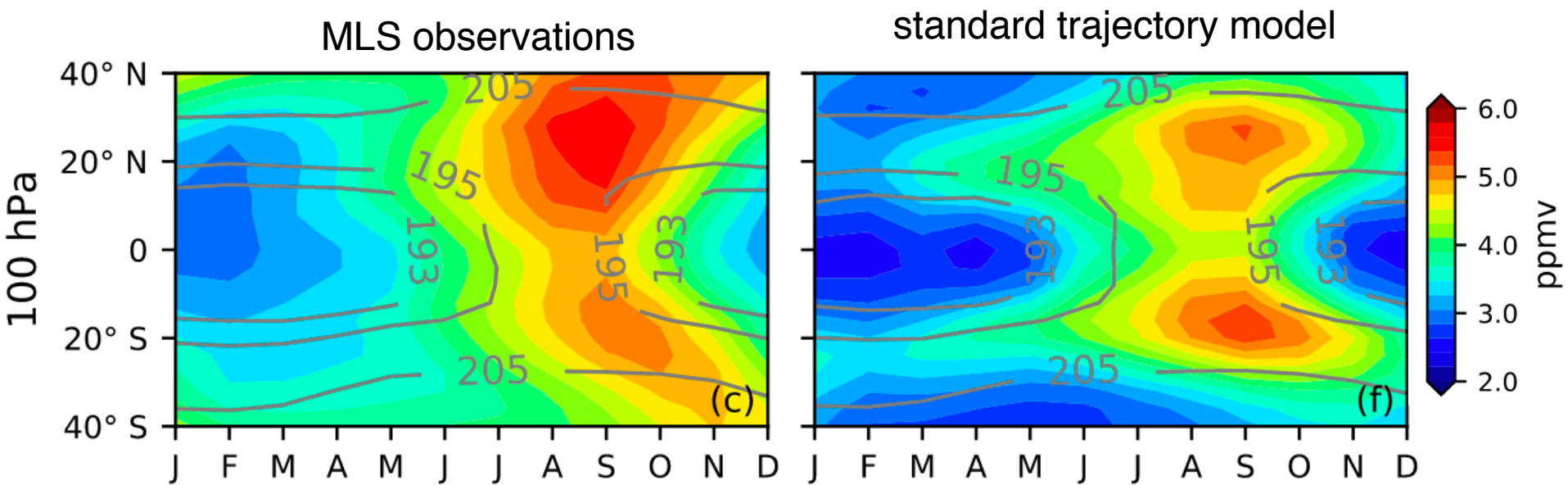
100 hPa zonal avg. seasonal cycle
2004-2018



100 hPa zonal avg. seasonal cycle
2004-2018

the asymmetry



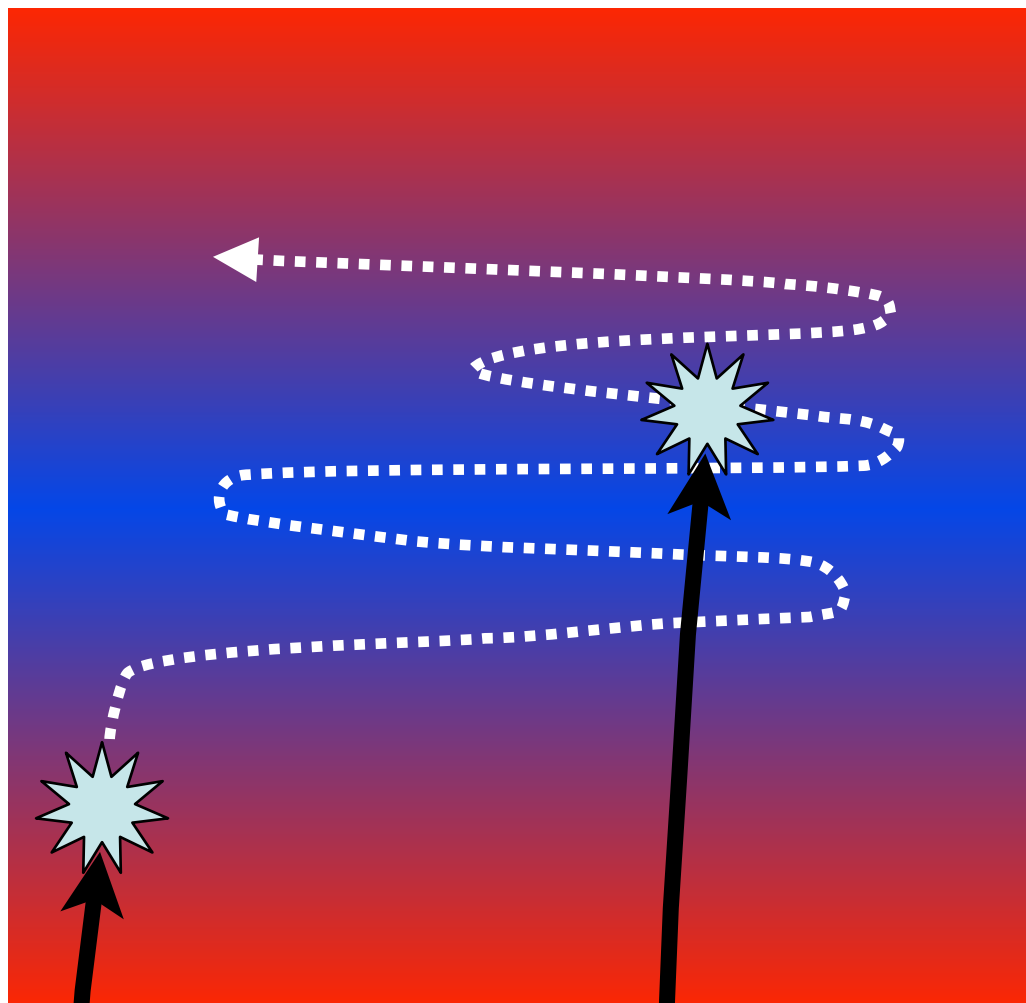


Can we add convection to this model?

400 K

380 K

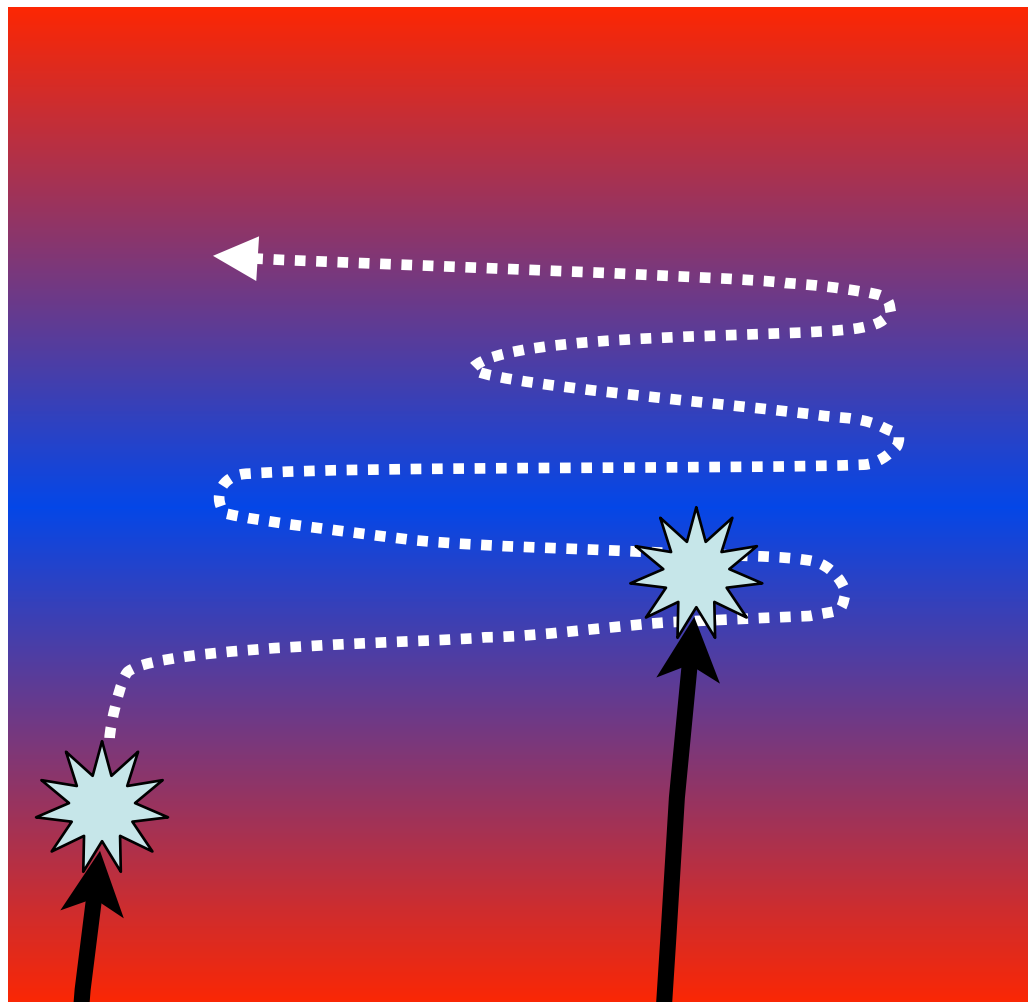
355 K

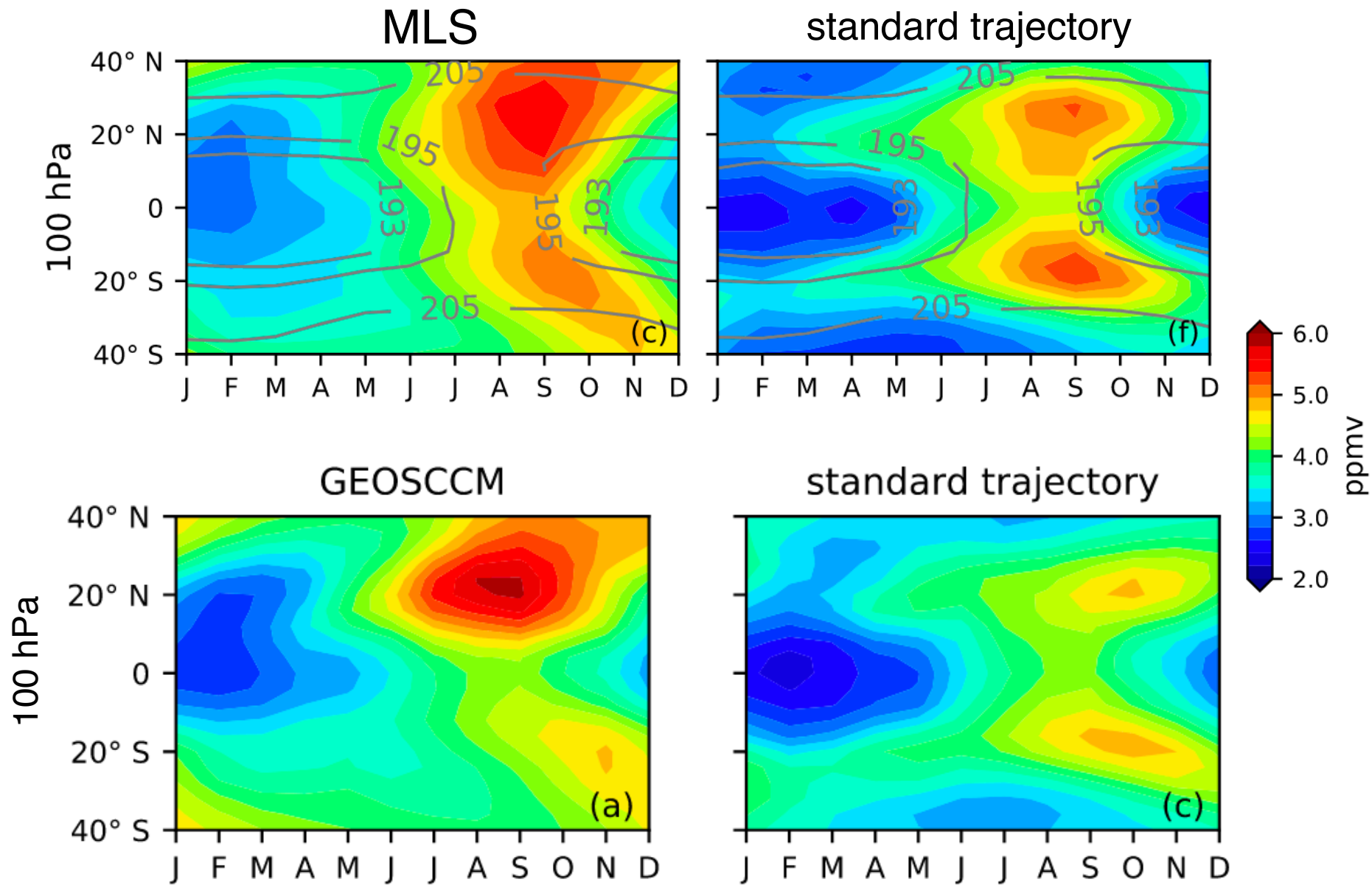


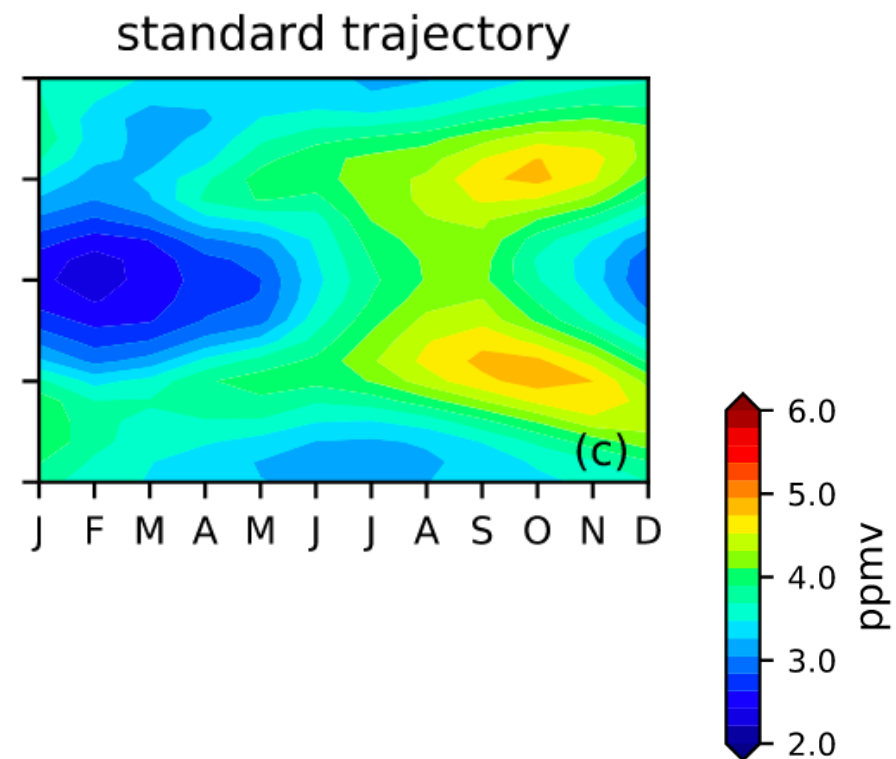
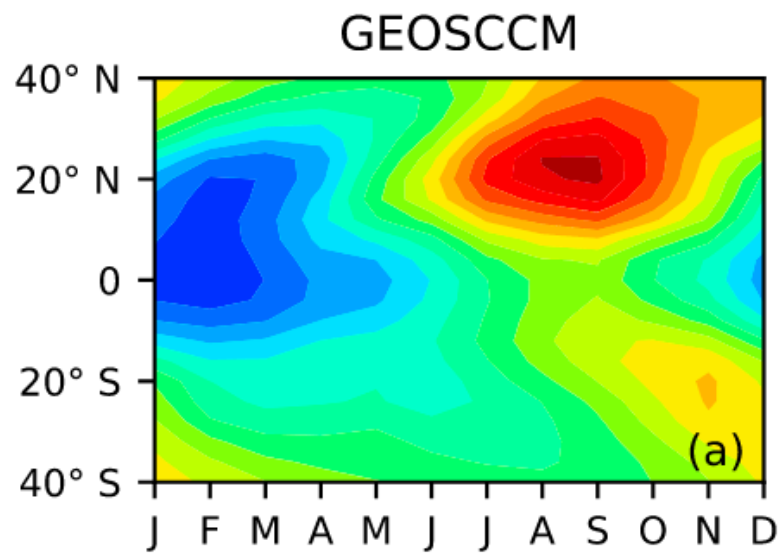
400 K

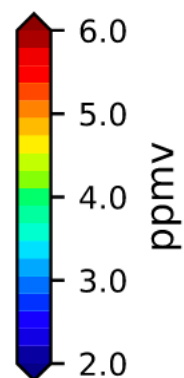
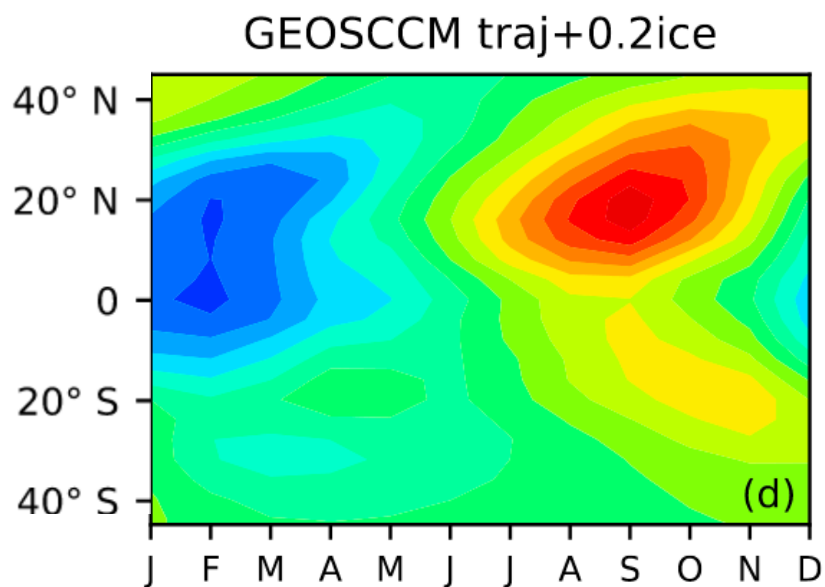
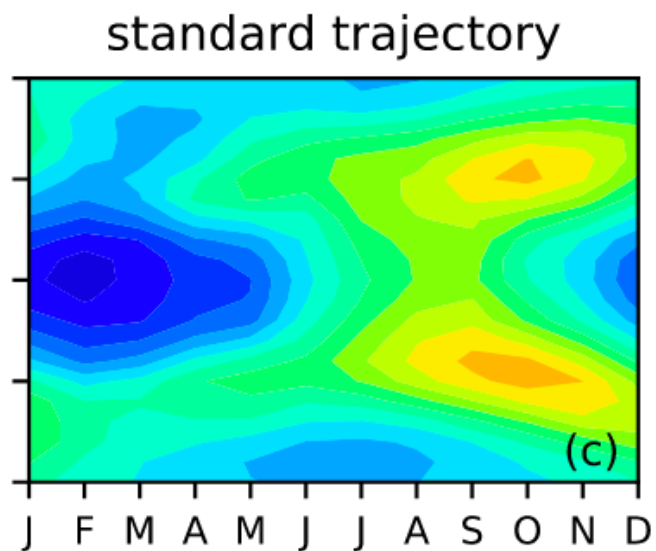
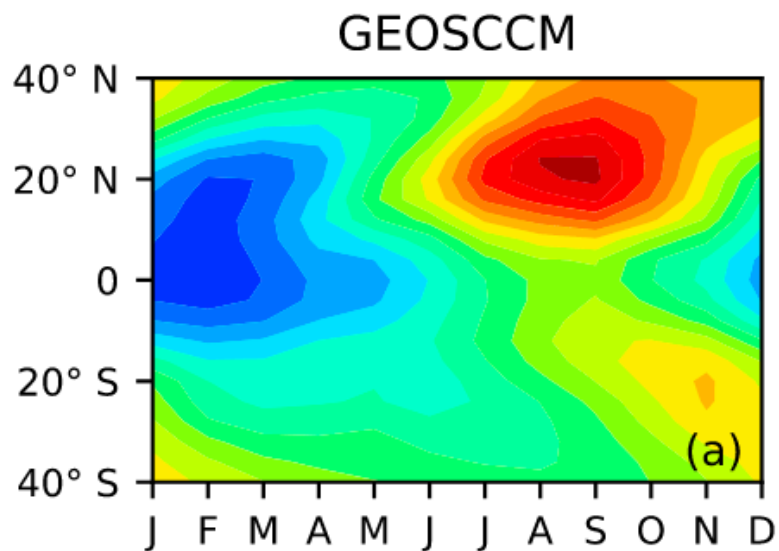
380 K

355 K

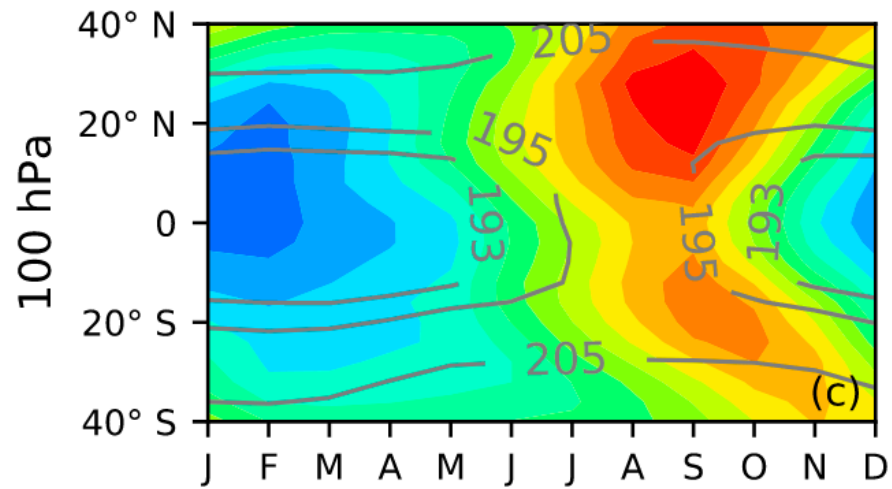




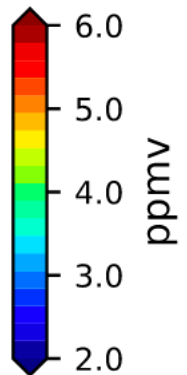
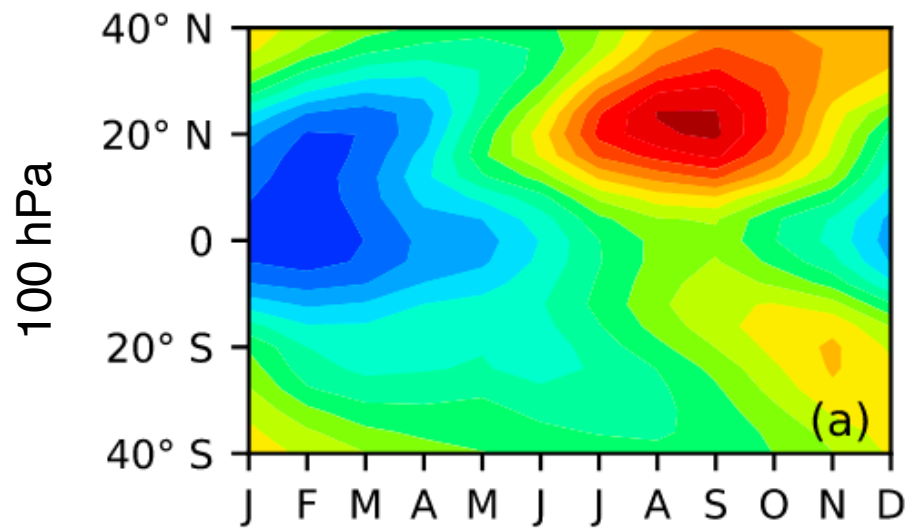




MLS



GEOSCCM



Conclusions

- Aura's measurements have greatly improved our understanding of the TTL
- Large-scale temperatures & transport are primary regulator of stratospheric humidity
- Microphysics increases humidity by ≈ 1 ppmv ($\sim 25\%$)
- Convection not too important, but could be regionally important in the lower stratosphere